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ENFOR PROJECT P-191

Harvesting Forest Biomass as an Alternative Fuel

by

Bowater Newfoundland Limited

Energie ENFOR de la Forêt
Energy ENFOR from the Forest

[redacted]

Contractors Final Report[1]
DSS Contract 079C.KH205-2-0011

ENFOR PROJECT P-191

Harvesting Forest Biomass as an Alternative Fuel

by

Bowater Newfoundland Limited

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Corner Brook, Newfoundland.

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AUGUST 1983

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FOREST BIOMASS AS AN ALTERNATIVE FUEL AT BOWATER NEWFOUNDLAND LIMITED - Project No. 10SC KL001-1-002

SUMMARY

Bowater Newfoundland Limited has conducted trials over a two year period, to assess the potential of utilizing forest biomass as an alternative fuel. The work was performed by Bowater but subsidized under the ENFOR program.

Two harvesting systems were studied as well as a variety of sites. Fuelwood was produced and burnt under summer, fall and winter conditions. Production and cost data are reported and oil equivalent values for forest biomass determined. These data are for specific conditions and need to be interpreted in this context.

Based on the information from forest biomass harvesting and burning experience, the following assessment can be made:

1. The trials confirm that harvesting and burning of hardwood chips is economic under conditions existing at Bowater Newfoundland Limited. These conditions are specified in the report and result in a green ton of chips being equivalent to 1.75 barrels of oil.

2. Harvesting and burning of hardwood chips is economically marginal or not viable at today's oil prices on a "stand alone" basis where a green ton of chips is equivalent to 1.0 to 1.2 barrels of oil.

3. The cost of oil has not escalated as forecasted prior to the trials. Labour and other costs have increased at a greater rate than oil prices during the period of the trials. Therefore, the economics are less favourable than predicted in 1981.

4. Of the two systems studied, System I proved to be superior. This system is capable of expansion and mainly delivers hardwood chips. The system is built around a reliable, high capacity chipper and one or more of these systems could provide significant quantities of alternative fuels for paper mills or other facilities.

5. System I has equipment which has performed well in North America for many years and all equipment except the chipper can be utilized for roundwood pulpwood harvesting.

6. System II was an attempt to integrate pulpwood and fuelwood production and to recover additional biomass in the form of softwood limbs and tops. This system could not produce biomass from limbs and tops at a production rate

to make the system economic. Production rates three to four times the rate achieved are necessary to compete with other forms of biomass. Although there is great potential in recovering limbs and tops for fuel, there are some major obstacles to overcome before production rates can be increased to make the fuel competitive with oil. The report discusses some of the areas for improvement.

7. Steam production burning bark only (12.9 wet tons/hour at 61% moisture) is in the range of 45,000 to 50,000 lbs/hour. Addition of 3.24 green tons/hour of hardwood chips (43% moisture) to the quantity of bark above increases steam production to 81,157 lbs./hour. By crediting the chips with the increased steam generation of the total mixture, the fuel equivalent value of the chips is increased. Under these conditions, a green ton of chips is equivalent to 1.75 barrels of oil. Mixing hardwood chips with bark increases boiler efficiency from the level of 40-45% (bark only) to 60-65% (bark and chips).

3. Although a green ton of biomass equates to 1.75 bbl/ton under conditions existing at Bowater Newfoundland Limited, this value cannot be projected for other sites where conditons are different.

   On a 'stand alone' basis (firing chips only), a green ton of hardwood chips is equivalent to 1.0 to 1.2 barrels of Bunker "C" oil (No. 6). The extra oil equivalent value at the Bowater Newfoundland site is due to improved boiler efficiency for the total bark-chip moisture versus the lower efficiency when burning wet bark only.

9. At 1.1 bbl/oil per green ton equivalent, hardwood chips cannot compete with oil at present prices. Even at the highest production rates, chips are at best marginal in cost with other fuels.

10. Although high production rates are possible with System I, these rates were governed by the capacity of existing boilers to burn solid fuel without serious pollution problems. Enough information was obtained to support production rates well in excess of trial production rates.

11. The chipper used for System I has very high production potential. Even when five skidders were used at Site 4, the chipper had a utilization factor of only 60%. Increased production can further reduce costs and impact favourably on the quantities of forest biomass that can be used as an alternative fuel.

12. To take advantage of increased production rates and use larger trucks to further reduce transportation costs would require major capital expenditures at the Bowater Mill. New boilers capable of burning more solid fuel, storage and a truck dumping facility are also required. At existing oil prices, these expenditures cannot be justified. More information is also needed as to the sources of economic forest biomass within trucking distance of the Mill. Present plans call for continuing harvesting of forest fuel to the capability of existing boilers and to operate the small self-dumping trucks for chip transportation.

13. The value of a green ton of chips at various oil prices and bbl/ton equivalents is as follows:

Cost of Oil/bbl	Value of a Green Ton	
	@ 1.75 bbl/ton	@ 1.1 bbl/ton
25.00	$43.75	$27.50
30.00	52.50	33.00
35.00	61.25	38.50

The current (May/83) cost of Bunker "C" oil is about $30.00 per barrel.

14. Actual cost for System I at the various sites varied between $40.00 to $50.00 per green ton. These costs include high rental costs and other factors which tend to increase costs for the trial periods.

On the basis of an ongoing operation, costs for a five skidder system is projected to be in the $30.00 to $35.00 per ton range. A detailed breakdown of these costs is recorded in Section 10.4.

15. The use of chips mixed with bark has improved the general operation of boilers 1 and 2. An improved feeding system for existing boilers would permit more chips to be burnt and increase steam generation from this source.

16. The only negative aspect of the trials was an increase in air pollution due to emission of particulates. By limiting the quantity of chips burnt, a measure of control is exercised. The Provincial Environment Department are monitoring the situation and permits to continue burning will be required.

17. Indications at this stage are that forest biomass may be harvested without detrimental impacts on future crop distribution and development.

18. The full forest management benefits of forest biomass harvesting have yet to be fully assessed. Among the positive aspects are (i) cleaner cutovers when planting is required; (ii) removal of hardwood sites for replanting of softwood species; (iii) clearing of substandard sites for subsequent drainage and planting of more tolerant species; or (iv) other silviculture improvement. Under normal circumstances the cost of preparing these sites for carrying out such improvements would be prohibitive. However, when credited with the value of fuelwood recovered, the procedures can be practical.

19. Harvesting of forest biomass must be a year round activity to justify operating the high cost of the required equipment. Winter fuelwood harvesting cannot take place on cutover sites left after pulpwood harvesting. Winter operations must be limited to pure hardwood sites or on substandard softwood sites which need to be cleared for forest management upgrading such as draining, fertilization and replanting.

20. In two years of trials, Bowater Newfoundland has developed confidence in a system for delivery of hardwood chips with the potential of supplying in excess of 200 green tons/day. One or more of these systems could supply a significant proportion of the steam energy needs of a paper mill or other facility. However at present oil prices, the economics of burning hardwood chips is marginal except under particular circumstances. Each mill needs to assess its particular potential for harvesting forest biomass as an alternative fuel.

1.0 INTRODUCTION

This is the final report on the harvesting of forest biomass as an alternative fuel. The work is being done by Bowater Newfoundland under a contract for Supply and Services Canada and is partially funded by ENFOR.

The project has run for almost two years and covers harvesting of biomass under summer, fall and winter conditions. Two systems for biomass harvesting were evaluated. Biomass from three different sources was assessed. These three sources were as follows: (1) residuals left on site after pulpwood harvesting - mainly hardwoods, (2) pure hardwood stands, and (3) limbs and tops from pulpwood harvesting - mainly softwoods.

During the period of these trials from July 1981 to February 1983, a total of 22,424 green tons of forest biomass was harvested and burnt for fuel. This fuel replaced Bunker C (No. 6) oil which is used to produce steam for the paper making process at the Bowater Newfoundland mill at Corner Brook.

Since the rapid increases in oil costs which were precipitated by OPEC in the nineteen seventies, there is increased interest by Governments and Industry in alternative energy sources. The forestry industry has the potential to supply a greater share of its energy needs from forest biomass. Because it is already involved in the harvesting and transportation of large volumes of wood and since it is located relatively close to the forest, the Pulp and Paper Companies should be in the best position to take advantage of the energy source represented by forest biomass. Much of the wood that could be used for energy is now left in the forest as a residue after pulpwood is harvested. However, to take advantage of this energy source, a combination of economic, technical and geographical factors must be favourable.

In recognition of the long term trends for oil with respect to price and supply, Bowater Newfoundland made a decision to carry out forest biomass harvesting and burning trials, assisted by the ENFOR program.

There are relatively few pure hardwood stands in Western Newfoundland. Therefore, the trials are focused on recovery of hardwood and softwood left on site after pulpwood harvesting and on an integrated pulpwood and fuelwood harvesting operation. These two systems are the basis of the present forest biomass program, although we now believe that selected pure hardwood stands are necessary to successfully carry out a winter program.

Bowater Newfoundland has, for many years, produced part of its steam energy requirements using forest biomass as a fuel. This is in the form of bark, recovered at the mill site and burnt in two biolers capable of utilizing solid fuel. The bark is mixed with Bunker C oil in these boilers. The first objective in the program is to replace this oil with an alternative energy source such as fuelwood.

The amount of bark as a percentage of steam energy has varied from a low of 3% in 1973 to a high of 12.0% in 1980. The total steam generated from bark and hardwood chips in 1981 represented 14.7% of steam requirements and 13.3% in 1982.

The intent of the trials is to determine whether it is possible to economically increase the amount of steam energy from forest biomass. There are many advantages in using locally produced fuels to replace imported oil if this can be done at a competitive cost. At present, forest biomass is at a disadvantage as it is competing against subsidized fuel. If a similar subsidy were available for forest biomass, the economics would be improved. Forest biomass harvesting is relatively labour intensive and can provide jobs for many Canadians.

There are also some advantages and disadvantages with respect to the environment. Forest biomass is a more environmentally acceptable fuel with respect to acid rain than is high sulphur oil. However, there are disadvantages in that particulates are higher when burning wood. The cost of installing equipment to meet the present air pollution standards is prohibitive on existing boilers at Bowater Newfoundland. Some of the above factors complicate and make difficult a clear cut answer when considering forest biomass as an alternative fuel. The trials provided a basis for a more rational assessment of this potentially valuable energy source. Although all issues have not been resolved we have a better perspective of what can be done and the cost of these fuels.

2.0 PROJECT OBJECTIVE & SCOPE

The project was designed with the following objectives in mind.

(1) To test and develop practical harvesting systems for the extraction and transportation of (i) hardwood residuals from previously logged cut-overs, and (ii) fuel wood and pulpwood in an integrated full tree harvesting operation in mixed softwood-hardwood stands.

(2) To assess the technical and economic feasibility of using forest biomass as an alternative fuel at the Bowater Newsprint Mill at Corner Brook, Nfld.

(3) To assess the impact of complete tree removal, with emphasis on disturbance to the site, and the silviculture implications regarding the future crop.

(4) To produce fuel wood in sufficient quantities to assess the handling, storage and combustion characteristics of this fuel.

3.0 APPROACH & METHODOLOGY

To meet these objectives, it was necessary to divide the trials into two separate harvesting operations, each system having its own equipment and support systems.

While in principle the trials appear similar to work already carried out in central Newfoundland by Price Nfld. (ENFOR Project P-143), various terrain elements and stand conditions made it significantly different. Much of the terrain in the western region is steep and extremely rugged. Moreover, the terrain is such that landing space is restricted and roads for the most part are steep. Because of this, shorter, lower capacity chip vans are used.

Many forest stands in western Newfoundland contain very large diameter trees having bulky crowns - sharply contrasting with the small diameter, compactly crowned trees of the central region. Such large trees are difficult and hazardous to handle. The heavy skidders used in Phase I and the fully mechanized system of Phase II were proposed to facilitate and expedite felling and handling in the western stands.

As was anticipated, the use of heavier equipment and the fully mechanized system increased costs over those for central Newfoundland. The trials have determined the magnitude of the increased costs. The spin off silviculture benefits of clearing ground for site preparation prior to planting/seeding is also evaluated.

Because of the cited differences in stand and operating conditions between western and central areas, it was necessary to conduct these trials using the techniques of two separate systems. The systems are as follows:

3.1 - *Phase 1 - System I*

Phase 1 harvested and chipped residuals left in areas previously logged for pulpwood. The principal source of residuals is the standing and downed hardwoods, with softwood tops, blowdowns, and small diameter trees contributing a lesser amount. Since harvesting of these residuals must take place before regeneration has progressed, it is preferable to move into these areas as soon as possible (one to three years) after pulpwood has been harvested. This has the added benefit of utilizing existing roads, skidder trails and landings.

The Phase I system consisted of three skidders delivering logs to the chipper landing. The logs were chipped in a -22" Morbark chipper and blown directly into containers mounted on pallet type trucks. The trucks delivered the chips directly to the Mill and were self dumping. The chips entered the Mill through an existing bark feeding system and were mixed with bark and blown to the boiler house storage bins. The mixture was then burnt in two boilers equipped to handle solid fuels.

3.2 - *Phase II - System II*

The Phase II system was an entirely separate operation for harvesting and chipping forest biomass. This system was an integrated full tree operation in mixed softwood-hardwood stands and produced both pulpwood and fuelwood. A Koehring feller forwarder cut and transported trees to roadside. At roadside the softwood trees went to a Hahn processor. The Hahn separates limbs and tops from pulpwood. The limbs and tops were left in "rows" and a mobile chipper converted this material to a size suitable for burning. All material was blown into containers and delivered to the mill site by truck. No difficulties were experienced in separating the hardwood-softwood component since the percentage of hardwood was low. With increasing hardwood component there would undoubtedly be some reduction in the pulpwood capacity of this system.

The intent was to maximize the recovery of forest biomass without increasing the cost of pulpwood harvesting.

Since the forest biomass project was in the nature of a trial, it was important to minimize capital expenditures for equipment that could not be subsequently used in pulpwood harvesting if biomass harvesting proved uneconomical. Therefore, only the skidders were purchased and all other equipment rented or hired on a contract basis. However, rental costs are high compared with depreciated costs and this is recognized in the analysis of costs. In the mill we were particularly fortunate in utilizing existing bark handling facilities to feed chips to the boilers and the self-dumping trucks also avoided capital costs which might prove redundant.

4.0 POTENTIAL FOR BIOMASS UTILIZATION

Bowater Newfoundland has burned bark in two of its six boilers for a number of years. The bark is a waste product from the wet barking process. Wet barking is the first step at the mill site to prepare pulpwood for conversion into paper. The wet bark is recovered, pressed and delivered to the boiler house for use as a fuel. Because the bark contains a high percentage of moisture (60 - 62% after pressing), boiler efficiency is low and the steam generating capability of the boiler is adversely affected. To increase the generating capacity of the two bark burning boilers, it is necessary to supplement bark fuel with oil. It is desirable to eliminate oil on these boilers and to maximize steam generation from the boilers using alternate fuels. This can be accomplished by burning bark of lower moisture content or supplementing bark with other biomass from the forest. One of the priorities of the present trial was to determine what quantity of forest biomass can be used with the existing bark to supply Nos. 1 & 2 boilers with solid fuel only and eliminate oil.

The immediate priority was to supply Nos. 1 & 2 boilers. Depending on the economics of forest biomass and the potential quantities of forest biomass available, a number of scenarios are possible. One scenario is to convert other boilers to burn forest biomass. Another scenario is to install a new boiler specifically designed to burn bark and other forest biomass. Before such a boiler can be designed, it is imperative that the supply of forest biomass can be maintained on a continuing basis. Information such as this was one of the objectives of the forest biomass trial.

Bowater Newfoundland does not have access to sawmill waste, therefore, solid fuel supply must come from bark produced at the mill and forest biomass from its forest holdings.

Bowater Newfoundland requires annually approximately 20,000 acres of forest land to provide the 463,000 cords of pulpwood to produce 403,000 tons of newsprint. If all the forest biomass on this acreage was available for burning and the Mill had boilers capable of burning this fuel, then it would be possible to completely replace the 515,000 bbls. of Bunker C oil now used to produce steam. However, all this biomass cannot be made available at an economic cost and the focus of the trials is to determine what part of this potential can be successfully utilized.

Bowater Newfoundland woodlands are divided into management units. Because of their locations closest to the mill, management units 14, 15 and 16 have potential for providing fuel in the form of forest biomass. The main potential is in management unit 15 as the Mill is located in the centre of this unit. The annual allowable cut for this unit is 92,000 cords. Assuming 23 cords per acre, the cut over area in this unit is 4000 acres/yr. Assuming recoverable biomass of 20 tons per acre, the potential forest biomass within a 50 mile radius of the Mill site is approximately 80,000 tons/year on a continuing basis. The above is the potential from one management unit which is located in an area closest to the Mill site. The reality is that a portion of this management unit is not accessible and the economically recoverable biomass throughout management unit 15 may be less than the 20 tons per acre cited above. As we progress with biomass harvesting trials in other areas, we will have a clearer picture of the biomass potential of this and other management units.

As the current requirements for biomass with existing boilers are about 30,000 tons/year, it is safe to assume there are sufficient quantities available within management unit 15 to provide a continuous supply. To increase production above this level will require either conversion of existing boilers or a new boiler. The results of these trials provided data to more accurately assess the potential of biomass as an alternative fuel for Bowater Newfoundland.

5.0 ENERGY IMBALANCE - WOODS vs. MILL

One of the problems of utilizing forest biomass as a fuel on a continuous basis is the difference in operating days between woodlands and mill operations. Woodlands operate on a 5 day week, 150-200 operating days/year, while the Mill must be supplied with energy 7 days per week and 359 operating days/year. To uniformly supply forest biomass over the full year would require large storage piles during the periods in spring and fall when woodlands' operations are completely shut down. The period of shutdown is approximately 60-70 days in April-May and 45-60 days in November-December. There may be scenarios for the future where large receiving facilities for fuel wood could minimize this shutdown period but at present large fuel wood storage piles are not comtemplated at the Bowater Newfoundland Mill due to space and other problems associated with storage of wood chips. These problems are - cost, increasing moisture content of stored fuel, loss of fibre, materials handling facilities, etc.

Storage problems are not serious for the five day versus seven day imbalance of woods - mill operations. However, longer periods require make up with oil for energy needs. Unit cost of biomass fuel increases when utilization is low since the high capital costs of chipper and harvesting equipment must be written off during fewer productive days. These considerations must be appreciated when evaluating forest biomass as an alternative fuel and "spot" cost for a short time frame must be considered in the larger context. With both winter and summer operating experience and by extending the trials over a sufficiently long period of time, we were able to produce realistic costs for supplying forest biomass on a continuous basis.

6.0 THE HARVESTING AREA

Much of the forest within a 100 km radius of the Corner Brook Mill is mixed softwood-hardwood, with white birch comprising most of this hardwood component. The hardwoods remain on the cutovers following harvesting for pulpwood. The harvesting of this hardwood resource, together with logging residue of softwood tops and branches for fuel at the Mill is the basis of these trials.

The choice of harvesting area had to conform to certain criteria. The site for a trial had to be relatively close to the Mill to keep transportation costs in line but far enough from the Mill to be representative of areas that can provide sufficient quantities of biomass to write off the large capital expenditure for harvesting and chipping equipment. The site terrain should be typical of conditions to be experienced within a future biomass harvesting area. The sites would use existing pulpwood road networks.

Three sites were harvested during these trials. The Blue Hill Brook and Tower Line sites are located in the Serpentine Lake region approximately 25 km west of Corner Brook. The Glide Lake site is located near Deer Lake about 50 km east of Corner Brook. Figures 1 and 2 show the location of these sites in relation to the Mill.

6.1 - *SITE DESCRIPTION*

6.1.1 - *Blue Hill Brook*

The site chosen for the Phase I trial is in an area of generally rough hilly terrain at a distance of 45 km by road from the Mill site. The area harvested during the period July 6th to November 15th covered 430 acres and produced 8,992 green tons of biomass. The yield per acre was 20.9 green tons.

The site lies on a moderate northwest facing slope and the soil is a deep, nutrient rich, loam to silt loam which is moderately well drained. The land capability for Forestry (Canada Land Inventory 1972) is a mixture of classes 2 and 3. This is a very rich site with better than average growing conditions for Newfoundland. The site originally supported a mature Balsam fir stand about 80 years old. The stand was cut over for pulpwood in 1978.

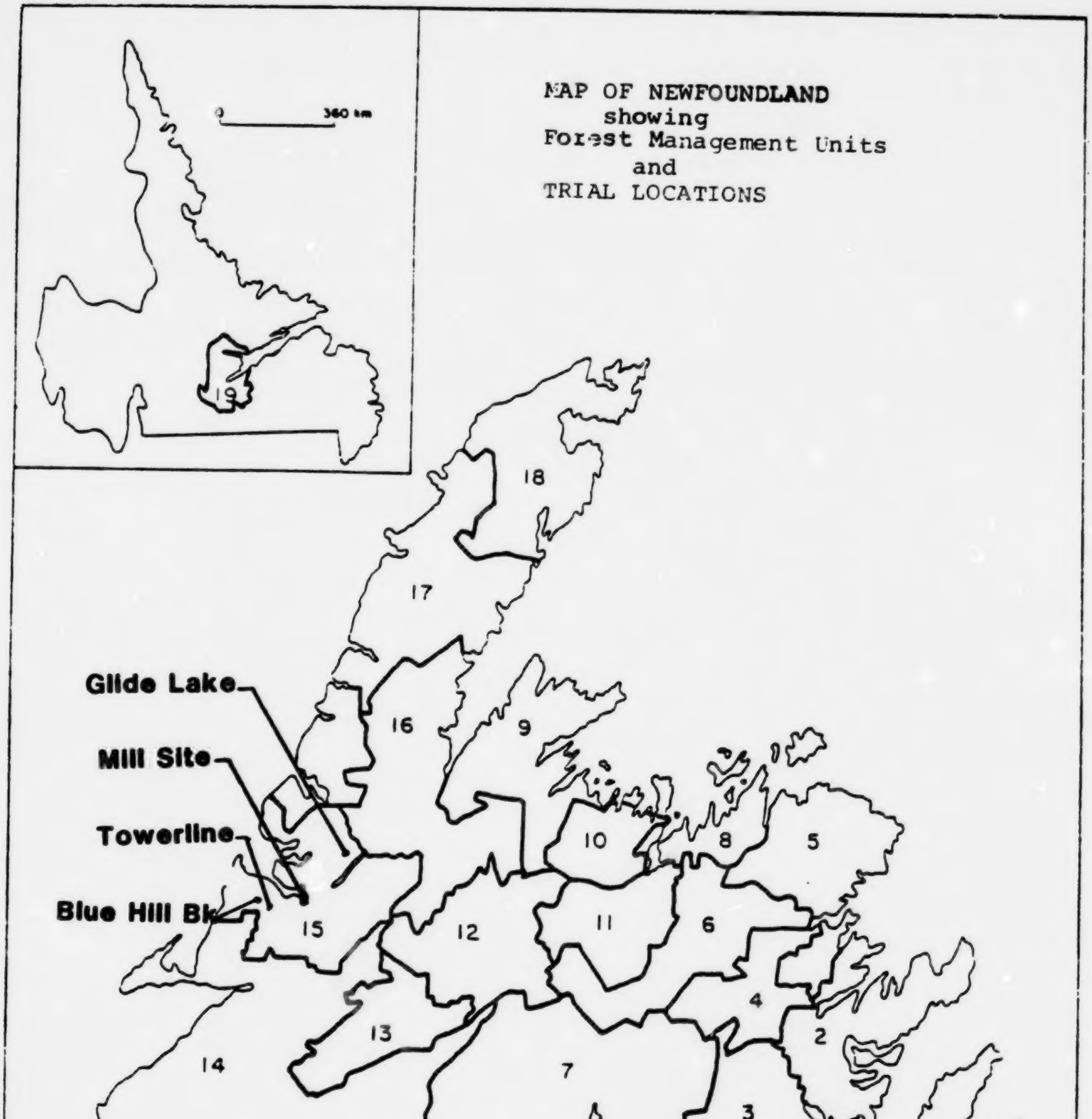
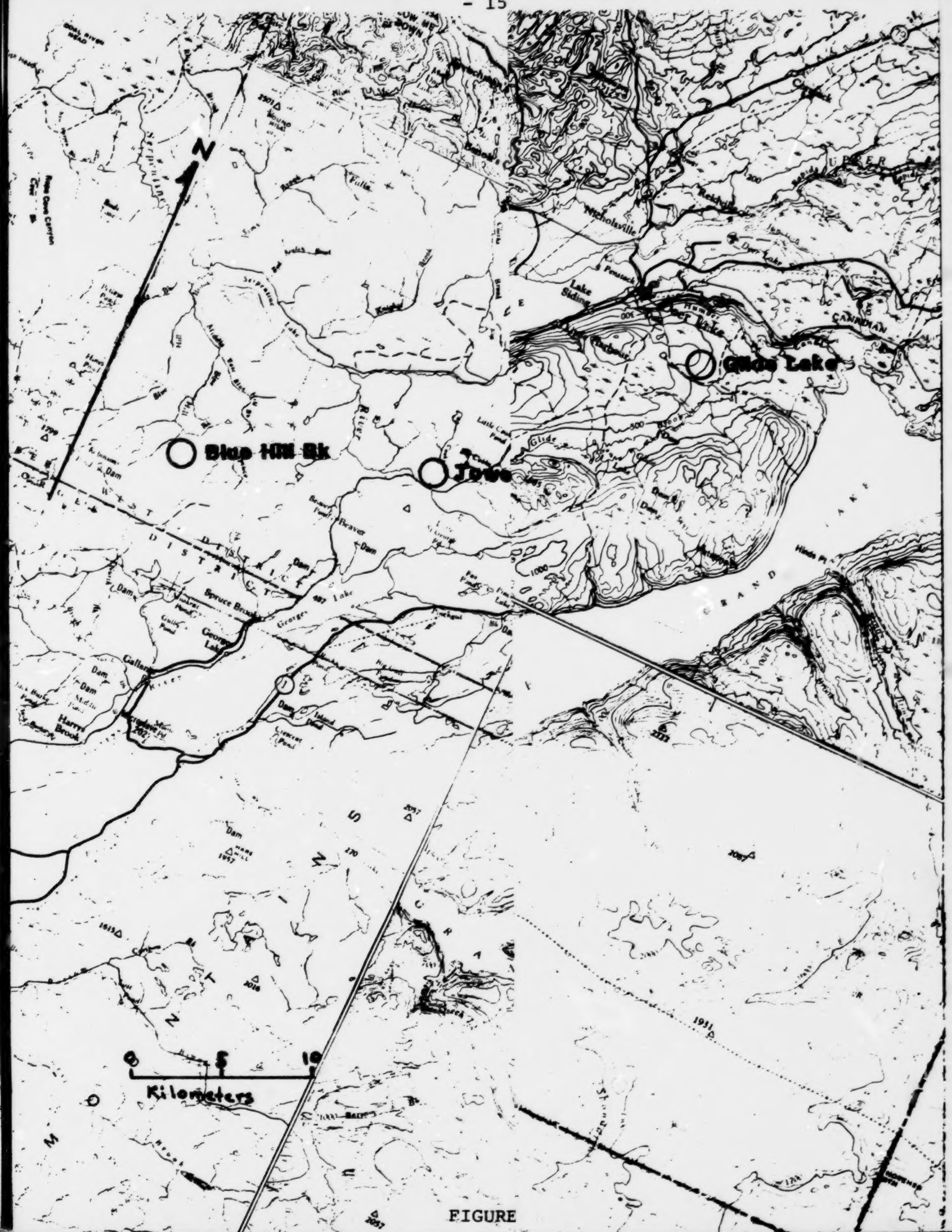

MAP OF NEWFOUNDLAND
showing
Forest Management Units
and
TRIAL LOCATIONS
0
360 km
19
18
17
16
9
Glide Lake
Mill Site
Towerline
Blue Hill Bk
15
14
13
12
11
10
8
5
6
4
7
3
2
1
1A
0
50 km

Figure 1


N
Blue Hill Bk
Jowe
Glide Lake
0
5
10
Kilometers
Nicholsville
Lake Siding
Glide
Deer Lake
CANADIAN
Grand Lake
George Lake
Spruce Brook
Harrys Brook
WEST DISTRICT

FIGURE

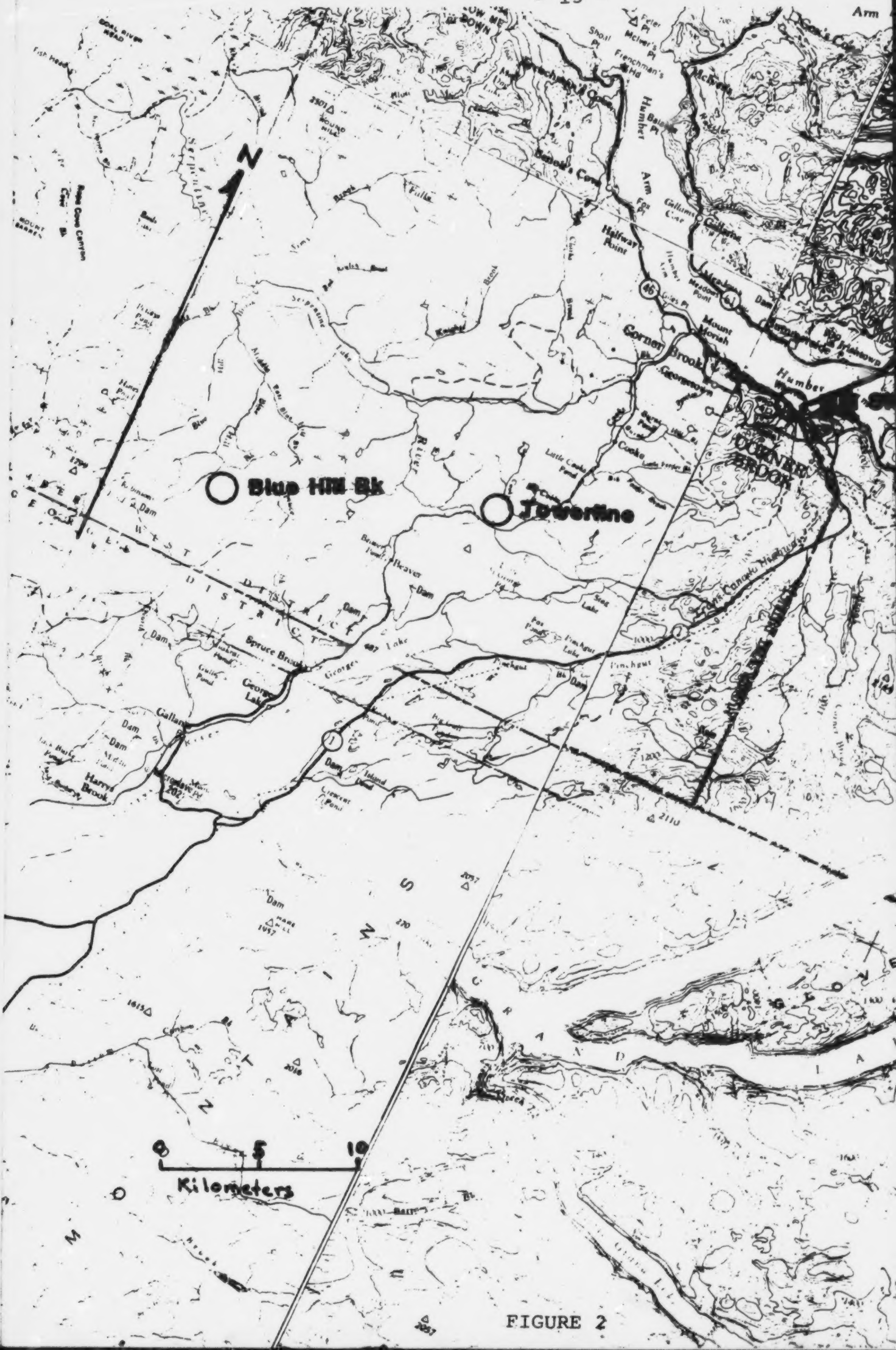
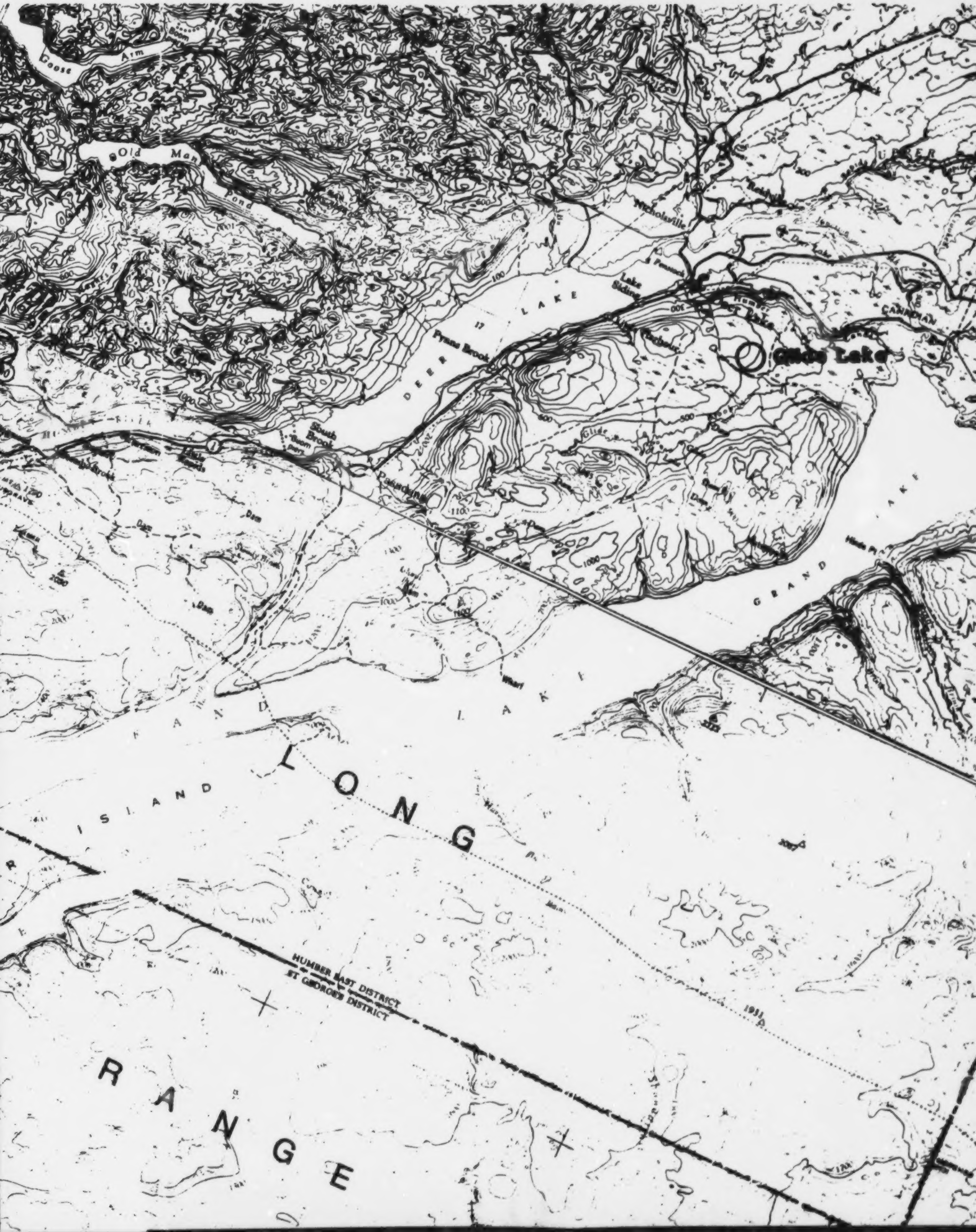

N
Blue Hill Bk
Towerline
0
5
10
Kilometers
Corner Brook
Humber Arm
Halfway Point
Mount Moriah
Spruce Brook
George's Lake
Harrys Brook
Pinchgut Lake
Trans Canada Highway
Grand Lake

FIGURE 2


Goose Arm
Old Man Pond
Nicholsville
Lake Sidings
Deer Lake
Glide Lake
DEER LAKE
Pynns Brook
South Brook
Pasadena
Glide
UPPER
CANADIAN
GRAND LAKE
LAKE
ISLAND
LONG
RANGE
HUMBER EAST DISTRICT
ST GEORGE'S DISTRICT
Dam
Wharf
1100
1000
500
100

The stand remaining after pulpwood harvesting is typical of cutovers in Western Newfoundland with a few large white birch and other scattered white birch and balsam fir. Approximately 75% of the residual stems had been knocked down during the pulpwood harvesting operation. The average diameter of stems is 18.3 cm. It is interesting to note that no trees with dbh less than 6 cm were found. This is typical of a mature fir stand on a very rich site. Stand make-up before biomass harvesting is shown in Table 1 and after harvest in Table 2.

The photographs of the area are indicative of the terrain, the mixed softwood-hardwood stands and the residues left after pulpwood harvesting. (Photos 1 - 5).

6.1.2 - Tower Line

After the close of the summer harvesting season on November 15th, 1981, it was decided to continue the Phase I trial in winter operating conditions. Because of the large proportion of biomass in downed stems and the heavy snowfall and severe snowdrifting in Western Newfoundland it was obvious that winter biomass harvesting was not practical in cutovers. The harvesting unit was moved to a mature white birch stand. Harvesting commenced on January 2nd, 1982, and continued until March 1982. During this time, 3,721 green tons of chips were harvested from 27 ha. This equates to an average yield of 138 tons per hectare.

The site supported a nearly pure white birch stand approximately 60 years old with a few balsam fir and white spruce scattered throughout. Table 3 shows stems per hectare prior to harvesting and Table 3A shows what was left after the trial. The average dbh of the stand was 14.3 cm and 85% of the stems were 18 cm dbh or less.

The site lies on a moderate, south facing slope. The land capability for Forestry (Canada Land Inventory 1972) is class 3. The soil is a deep nutrient rich

TABLE 1

STAND TABLE - ALL SPECIES

SERPENTINE BIOMASS TRIAL

(Stems per Hectare)

Dbh (cm)	White Birch Standing	White Birch Down*	Balsam Fir Standing	Balsam Fir Down	Black Spruce Standing	Black Spruce Down	Total Standing	Total Down
6	-	-	1	1	-	1	1	2
8	-	10	-	-	1	3	1	13
10	1	18	2	10	1	1	4	29
12	2	28	1	15	-	6	3	49
14	6	22	-	15	1	3	7	40
16	9	28	1	13	-	4	10	45
18	6	20	2	10	1	3	9	33
20	3	16	-	6	-	3	3	25
22	3	11	-	2	-	3	3	16
24	1	8	-	3	-	-	1	11
26	3	6	-	3	-	-	3	9
28	1	3	-	1	-	-	1	4
30	2	4	1	3	-	1	3	8
32	3	2	-	3	-	1	3	6
34	2	2	1	2	-	-	3	4
36	3	3	-	-	-	-	3	3
38	1	1	-	1	-	-	1	2
40	2	1	-	-	-	-	2	1
42	3	-	-	-	-	-	3	-
44	1	1	-	-	-	-	1	1
50	1	-	-	-	-	-	1	-
60	1	-	-	-	-	-	1	-
TOTAL	54	184	9	88	4	29	67	301

*Down includes broken pieces large enough to skid

TABLE 2 Post-treatment Stand Table (Stems/ha.) for All Species, for the Blue Hill Biomass Experimental Area

Dbh (cm)	White Birch Standing	White Birch Down	Balsam Fir Standing	Balsam Fir Down	Black Spruce Standing	Black Spruce Down	Total Standing	Total Down
6	-	-	-	1	-	-	-	1
8	-	7	1	-	-	-	1	7
10	1	12	=	4	1	1	2	17
12	-	17	-	5	-	2	-	24
14	-	9	-	3	-	2	-	14
16	-	11	-	6	-	-	-	17
18	-	9	-	3	-	-	-	12
20	-	3	-	2	-	1	-	6
22	-	5	-	1	-	-	-	6
24	-	1	-	1	-	-	-	2
26	-	1	-	1	-	-	-	2
28	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-
32	-	-	-	1	-	-	-	1
TOTAL	1	75	1	28	1	6	3	109

TABLE 3 Pre-treatment Stand Table (Stems/ha.) by Species, for the Tower Line Biomass Experimental Area

Dbh (cm)	White Birch Standing	White Birch Down	Balsam Fir Standing	Balsam Fir Down	Black Spruce Standing	Black Spruce Down	Total Standing	Total Down
6	20	1	49	-	1	-	70	1
8	84	2	34	-	1	-	119	2
10	142	5	20	-	1	-	163	5
12	191	3	15	-	1	-	207	3
14	197	5	15	-	-	-	212	5
16	191	1	10	-	1	-	202	1
18	143	1	9	-	1	-	153	1
20	90	1	7	-	-	-	97	1
22	48	1	8	-	1	-	57	1
24	22	-	3	-	-	-	25	-
26	13	-	4	-	-	-	17	-
28	4	-	3	-	-	-	7	-
30	2	-	2	-	-	-	4	-
32	1	-	2	-	-	-	3	-
34	-	-	-	-	-	-	-	-
36	-	-	1	-	-	-	1	-
38	-	-	-	-	-	-	-	-
40	1	-	-	-	-	-	1	-
TOTAL	1,149	20	182	0	7	0	1,338	20

TABLE 3A Post-treatment Stand Table (Stems/ha.) for All Species for the Tower Line Biomass Experimental Area

Dbh (cm)	SPECIES							
	White Birch		Balsam Fir		Black Spruce		Total	
	Standing	Down	Standing	Down	Standing	Down	Standing	Down
6	5	24	3	3	-	1	8	28
8	6	60	2	6	1	-	9	66
10	13	62	2	10	-	-	15	72
12	8	45	1	3	-	-	9	48
14	5	21	-	3	-	-	5	24
16	2	10	-	2	-	-	2	12
18	-	7	-	-	-	-	-	7
20	-	-	-	-	-	-	-	-
22	-	1	-	1	-	-	-	2
24	-	1	-	-	-	-	-	1
TOTAL	39	231	8	28	1	1	48	260

loam. This is an above average site for Newfoundland but is typical for pure hardwood stands in Western Newfoundland.

6.1.3 - *Glide Lake*

The site chosen for the Phase II trial is a relatively flat, somewhat wet area east of Deer Lake approximately 50 km from the Mill. Pulpwood harvesting operations were ongoing in the area, salvaging spruce budworm killed wood. A 13.8 ha area was outlined for the study and 378 tons of biomass plus 1836 M^3 of pulpwood were harvested from this area.

The site was on generally flat smooth terrain. Imperfectly and poorly drained loamy soils are common to the area. The land capability for Forestry (Canada Land Inventory, 1972) is a mixture of classes 4 and 5.

The stands logged during the trial were second growth stands resulting from natural regeneration after logging in the 1930's. The area was severely damaged by the spruce budworm in the late 1970's and approximately 65% of the stand was killed. The average dbh of the stems was 11.4 cm and stand height ranged from 9-16 metres. Tables 4 and 4A show stems per hectare before and after harvest.

6.2 - SURVEY METHOD

In all areas, plots were established before harvesting so that pre and post harvesting measurements of stand conditions and ground disturbance could be made. The survey procedures were developed by the Newfoundland Forest Research Centre and are shown in Appendix 1.

6.3 - ENVIRONMENTAL IMPACT

The only environmental impact measured during the trial was the amount of ground disturbance during harvesting operations. This varied from area to area depending on the time of the year that logging took place and the method of logging.

TABLE 4

PRE-HARVESTING MEASUREMENT
STAND TABLE - ALL SPECIES
GLIDE LAKE BIOMASS TRIAL
(STEMS/HA.)

Dbh (cm)	Balsam Fir				Black Spruce				White Birch				Speckled Alder				Larch				Total			
	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total
6	206	825	74	1105	25	1	-	26	36	7	1	44	94	-	3	97	-	-	-	-	361	833	78	1272
8	222	426	74	722	18	6	-	24	37	10	-	47	17	-	1	18	-	-	-	-	294	442	75	811
10	160	313	56	529	7	-	-	7	24	3	3	30	1	-	-	1	-	-	-	-	192	316	59	567
12	144	210	49	403	10	1	-	11	8	7	-	15	-	-	-	-	-	-	-	-	162	218	49	429
14	160	156	32	348	11	-	3	14	18	6	-	24	-	-	-	-	-	-	-	-	189	162	35	386
16	114	175	35	324	24	3	1	28	6	4	-	10	-	-	-	-	1	-	-	1	145	182	36	363
18	78	99	17	194	14	3	-	17	3	-	-	3	-	-	-	-	-	-	-	-	95	102	17	214
20	47	96	25	168	11	-	3	14	3	1	-	4	-	-	-	-	-	-	-	-	61	97	28	186
22	35	47	8	90	7	-	3	10	4	1	3	8	-	-	-	-	-	-	-	-	46	48	14	108
24	36	61	11	108	11	1	6	18	-	3	-	3	-	-	-	-	-	-	-	-	47	65	17	129
26	15	26	4	45	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	16	26	4	46
28	7	17	3	27	4	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-	11	17	4	32
30	3	7	3	13	-	1	-	1	-	1	-	1	-	-	-	-	-	-	-	-	3	9	3	15
32	-	4	-	4	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	4	1	6
34	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
36	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	2
otal	1228	2464	392	4084	144	16	18	178	139	43	7	189	112	-	4	116	1			1	1624	2523	421	4568

L - Live
SD - Standing Dead
DD - Downed Dead

TABLE 4A

POST HARVESTING MEASUREMENT

STAND TABLE - ALL SPECIES

GLIDE LAKE - BIOMASS TRIAL (STEMS/HA.)

bh	Balsam Fir				Black Spruce				White Birch				Speckled Alder				Larch				Total			
lass	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total	L	SD	DD	Total
6	31	50	25	106	7			7	3		4	7	40			40					81	50	29	160
8	14	15	11	40	11	10		21	1	1		2	3			3					29	26	11	66
10	3	4	3	10	4	11	1	16			1	1									7	15	5	27
12			3	3		8		8														8	3	11
14			4	4	3	7		10	3			3									6	7	4	17
16					1	10	1	12	1			1									2	10	1	13
18			1	1	1	8		9													1	8	1	10
20																								
22						1		1														1		1
24						3		3														3		3
26						1		1														1		1
28																								
30																								
32																								
34																								
36																								
tal	48	69	47	164	27	59	2	88	8	1	5	14	43			43					126	129	54	309

Sub-merchantable (5m x 5m Plots) Post Measurement 60 stems/hecta

6.3.1 - *Blue Hill Brook*

Tables 5 and 5A show the pre and post harvesting disturbance in the Blue Hill Brook harvesting area. This area had previously been logged for pulpwood and 61.5% of the area measured had some type of disturbance resulting from the original pulpwood harvest. The total disturbed area after biomass harvesting was 72.5% or an increase of 11% during biomass harvesting operations. Most of the disturbance both before and after harvesting consisted of cull logs and slash on the ground. Actual soil disturbance (types 1-12) by all causes increased from 13.8% to 26.9% during biomass harvesting.

6.3.2 - *Tower Line*

Because of snow cover at the time plots were established in this area, pre-treatment ground disturbance could not be measured. However, this area was an undisturbed semi-mature birch stand and visual observations in uncut portions of the stand indicate that pre-harvest disturbance was nil. Table 6 shows the disturbance after biomass harvesting. A total of 21% of the ground surface had some type of disturbance. Most of this disturbance (11.9%) consisted of debris heaps.

TABLE 5 Results of pre - treatment ground surface disturbance study, Blue Hill biomass experimental area.

	Disturbance Type										
Disturbance Cause	1	2	3	4	5	6	7	8	9	10	Total
Undisturbed	-	-	-	-	-	-	-	-	-	-	38.5
Bulldozed skid trail	-	1.1	0.8	0.2	-	-	0.1	-	-	-	2.2
Unbulldozed skid trail	0.9	2.2	0.3	0.4	-	-	3.6	-	0.1	-	7.5
Bulldozed landing	-	-	0.1	-	-	-	-	-	-	-	0.1
Unbulldozed landing	0.3	0.3	-	-	-	-	0.4	0.1	-	0.6	1.7
Road surface	-	-	-	-	-	0.8	-	-	-	-	0.8
Till heap	-	-	-	-	0.1	0.2	-	-	-	-	0.3
Debris heap	-	-	-	-	-	-	-	-	-	46.0	46.0
Uprooted tree/stump	-	0.7	0.1	-	-	-	0.2	-	-	1.1	2.1
Undetermined	-	0.5	-	-	-	-	0.3	-	-	-	0.8
TOTAL	1.2	4.8	1.3	0.6	0.1	1.0	4.6	0.1	0.1	47.7	100.0

1. Humus layer exposed
2. Mineral soil exposure < 10 cm
3. Mineral soil exposure 10-25 cm
4. Mineral soil exposure > 25 cm
5. Mineral soil deposits 10-25 cm
6. Mineral soil deposits > 25 cm
7. OM/debris/soil mixture < 10 cm
8. OM/debris/soil mixture 10-25 cm
9. OM/debris/soil mixture > 25 cm
10. Cull log/slash

TABLE 5A Results of post-treatment ground surface disturbance study, Blue Hill biomass experimental area.

Disturbance Cause	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Undisturbed	-	-	-	-	-	-	-	-	-	-	-	-	-	27.5
Bulldozed skid trail	-	0.6	0.6	0.8	-	-	-	0.5	0.1	-	-	-	-	2.6
Unbulldozed skid trail	2.8	4.9	2.3	1.2	-	0.3	-	3.7	1.7	0.4	0.2	0.3	0.8	18.6
Butt end gouge	-	0.3	-	-	-	-	-	-	-	-	-	-	-	0.3
Bulldozed landing	-	-	0.2	-	-	-	-	-	-	-	-	-	-	0.2
Unbulldozed landing	-	-	-	0.2	-	-	-	0.3	0.1	-	-	-	0.4	1.0
Till heap	0.1	0.2	-	-	-	-	0.8	-	-	0.2	-	-	-	1.3
Debris heap	-	0.1	-	-	0.2	-	-	-	-	0.1	-	-	44.1	44.5
Uprooted tree/stump	0.1	0.7	0.3	0.2	-	-	-	-	0.1	-	-	-	0.3	1.7
Undetermined	0.7	0.7	0.2	-	-	-	-	0.7	-	-	-	-	-	2.3
TOTAL	3.7	7.5	3.6	2.4	0.2	0.3	0.8	5.2	2.0	0.7	0.2	0.3	45.6	100.0

1. Humus layer exposed
2. Mineral soil exposed < 10 cm
3. Mineral soil exposed 10-25 cm
4. Mineral soil exposed > 25 cm
5. Mineral soil deposits < 10 cm
6. Mineral soil deposits 10-25 cm
7. Mineral soil deposits > 25 cm
8. Organic matter/debris/soil mixture < 10 cm
9. Organic matter/debris/soil mixture 10-25 cm
10. Organic matter/debris/soil mixture > 25 cm
11. Muck ≤ 10 cm
12. Muck > 10 cm
13. Cull log/slash

Table 6 Results of the Post-treatment Ground Surface Disturbance Study, Towerline Biomass Experimental Area

Disturbance Cause	Disturbance Type 1	2	3	4	5	6	Total
Undisturbed	-	-	-	-	-	-	79.0
Debris heap	-	-	-	-	-	11.9	11.9
Uprooted tree/ stump	0.1	0.4	0.1	-	-	-	0.6
Undetermined	0.2	-	-	0.2	-	-	0.4
Unbulldozed skid trail	1.5	0.1	-	6.3	0.2	-	8.1
Total	1.8	0.5	0.1	6.5	0.2	11.9	100.0

1. Mineral soil exposure $<$ 10 cm
2. Mineral soil exposure 10-25 cm
3. Mineral soil exposure $>$ 25 cm
4. Organic matter/debris/soil mixture $<$ 10 cm
5. Organic matter/debris/soil mixture 10-25 cm
6. Cull log/slash

6.3.3 - *Glide Lake*

Post harvest disturbance measurements could not be made because of snow cover in the area at the end of harvesting operations. Pre-harvest disturbance consisted of the uprooted stumps of insect killed trees that had blown down. Disturbance during harvesting varied with conditions on the site.

6.4 - *REGENERATION AND SILVICULTURE*

6.4.1 - *Blue Hill Brook*

Table 7 shows regeneration status both before and after biomass harvesting in the Blue Hill Brook area. 40% stocking of 4 M^2 plots is generally considered the minimum required for adequate regeneration. While this area has 41% softwood stocking Bowater does not consider this adequate on this better than average site. A more detailed regeneration survey of the entire area will be made in order to develop a regeneration plan for the area. The increased level of hardwood stocking after harvest is due to sprouting from roots and stumps.

The large diameter white birch stems typically left on cutovers after pulpwood harvesting in Western Newfoundland are an impediment to subsequent silvicultural operations. Removal of these stems for use as fuel will make any future work on the site much easier.

6.4.2 - *Tower Line*

Because of excessive snow cover when plots were established, no pre-harvest regeneration counts could be made. Visual observations indicate that softwood stocking both before and after harvest is nil and that the area will regenerate to white birch by sprouting. Since this is an above average

TABLE 7

REGENERATION BEFORE AND AFTER HARVESTING

BLUE HILL BROOK

Species	Stems/hectare		% Stocking	
	Precut	Postcut	Precut	Postcut
Balsam Fir	6,717	5,380	39	39
White Spruce	485	173	5	2
Total Softwood	7,202	5,553	41	41
White Birch	9,912	13,802	74	82
Other Softwood	243	295	3	5
Total Hardwood	10,155	14,097	75	82

site, Bowater would like to establish a softwood plantation on the site. This is not practical, however, because of the restrictions placed on the use of herbicides for site preparation in Newfoundland.

6.4.3 - *Glide Lake*

Post harvest regeneration counts could not be made because of snow cover. The area had good softwood regeneration before harvest and this was not disturbed except where deep rutting by the Koehring caused the undercarriage to scuff the ground between the ruts.

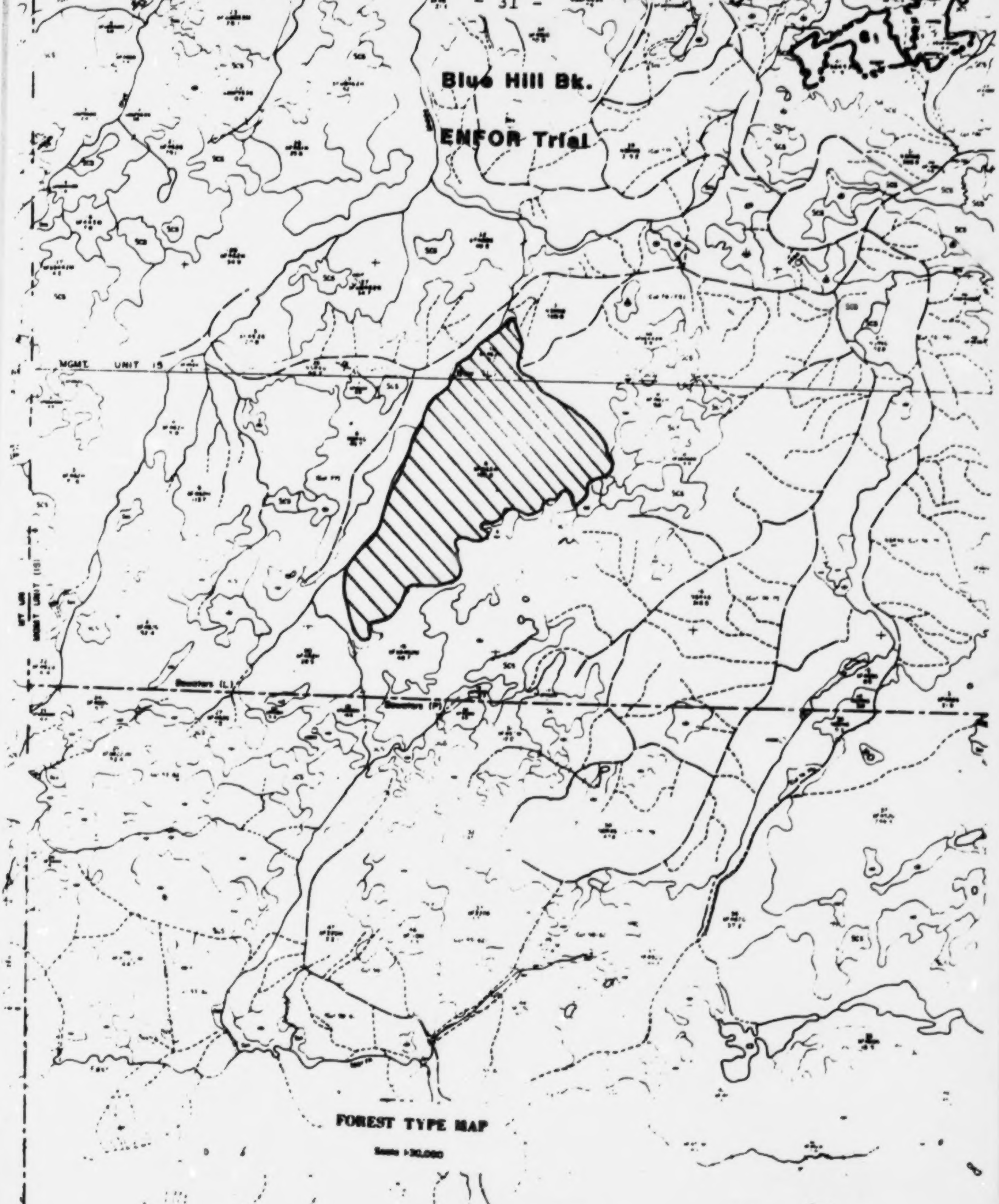
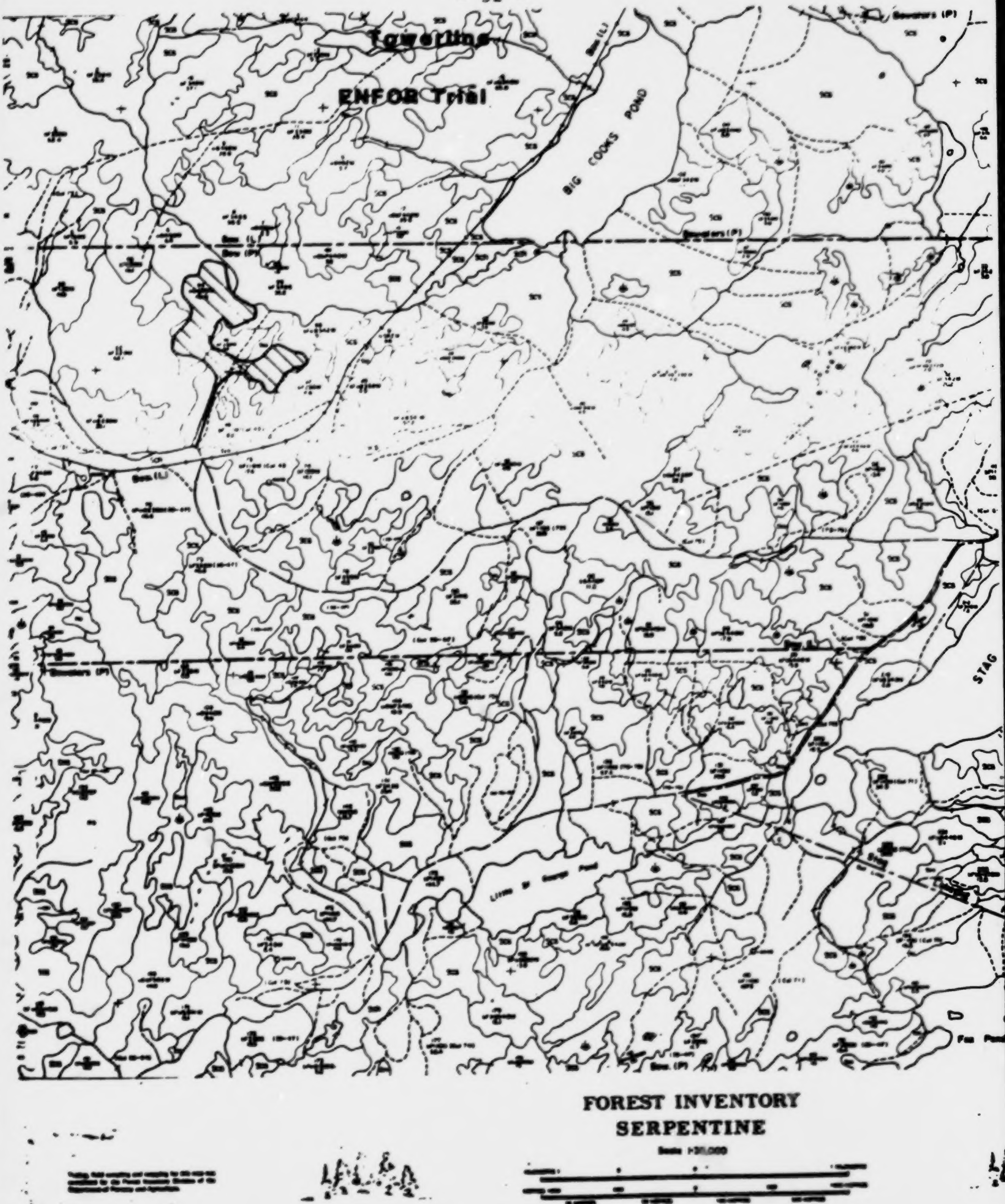

Blue Hill Bk.
ENFOR Trial
MGMT. UNIT 15
FOREST TYPE MAP
Scale 1:30,000

Figure 3


Towerline
ENFOR Trial
BIG COOKS POND
STAG

FOREST INVENTORY
SERPENTINE

Scale 1:[illegible]

Figure 4

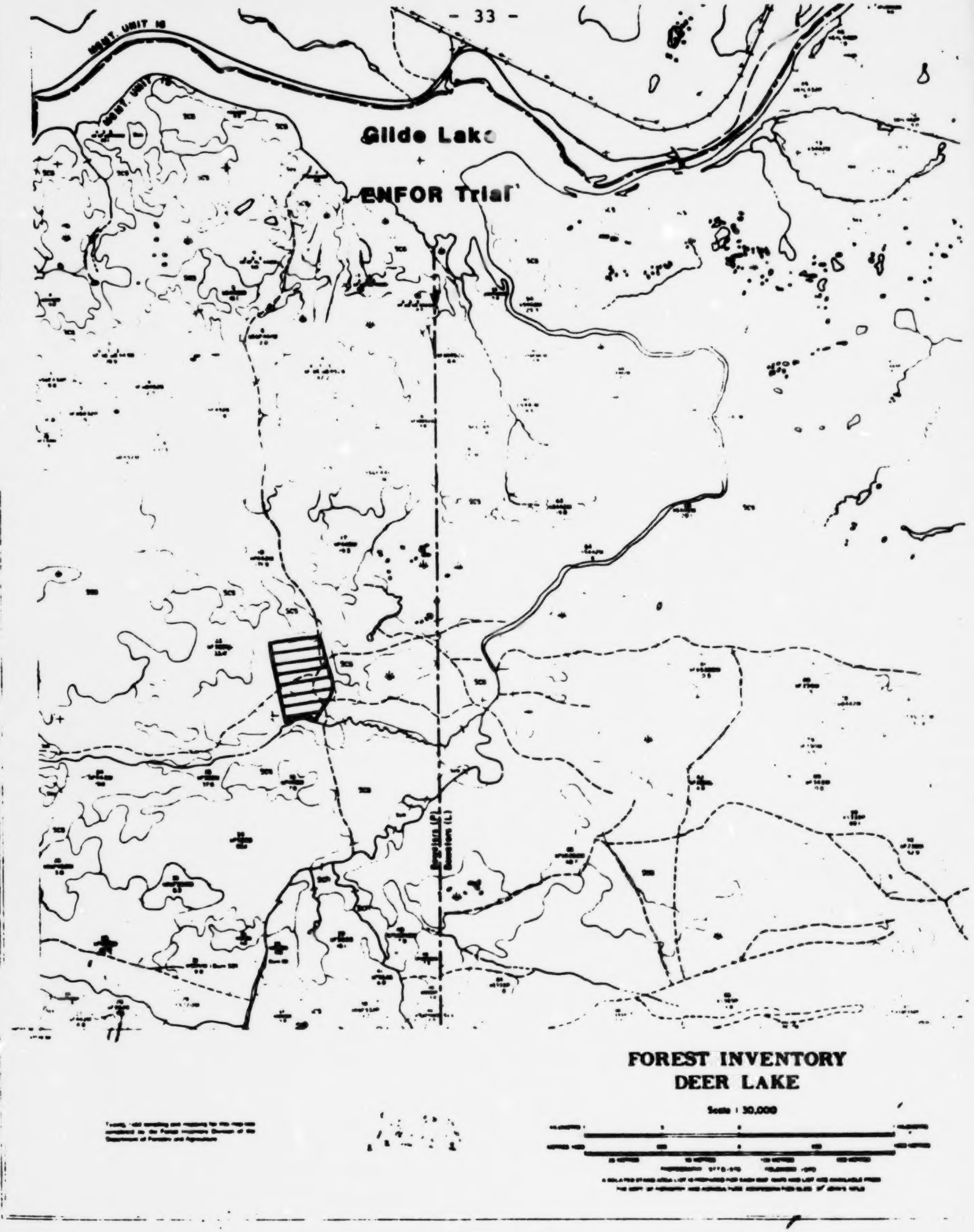

Glide Lake
ENFOR Trial
MGMT. UNIT 16
FOREST INVENTORY
DEER LAKE
Scale 1:30,000

Figure 5

7.0 DESCRIPTION OF PROJECT EQUIPMENT

7.1 - *PHASE 1 - SYSTEM 1*

7.1.1 - *Harvesting*

For transport to roadside, the Timberjack model 450 cable skidder was selected as having the necessary horsepower and traction to skid the trees to the landing for processing.

3 Timberjack Model 450 Skidders

Engine: G-M -4-53 turbo charged to give 144 flywheel horsepower at 2500 rpm. Single stage torque converter with Clark full powershift transmission - 3 speeds forward and 3 reverse.
Axles: Eaton heavy duty W5128, of the outboard planetary type. Oscillation ±15°. No spin differentials front and rear.
Hydraulic pump of the gear type, 31 U.S. gpm at 2500 rpm and 200 psi.
Electrical system 12 volts.
Winch: Gearmatic 119 with 30,000 pounds line pull.
Tyres: United 23.1 x 26 LS-2

These skidders have generally performed well on this job, and have justified the decision to go to a larger, stronger machine with more horsepower and wider tires.

7.1.2 - *Chipping*

The chipper selected was a portable one with an infeed deck, and a discharge spout with some mobility of discharge direction. It is set up at a landing, and the skidders feed into it dropping their loads within reach of the knuckle-boom loader. As the immediate area is cleared of birch, then the chipper is moved to a new landing, using a Mack truck with a 5th wheel attachment. Moving time takes only an hour or so under most conditions.

At the start the chipper was set up with some 12 extra sets of knives, and arrangements were made to have the knives ground in the mill grinding shop. This has worked well.

7.1.2 Cont'd.

1 Morbark Model 22RXL Total Chiparvester

Engine: Cummins 450K - 450 horsepower.
Chipper: L.H. Rotation, Horizontal feed, end discharge, 75 inches diameter, 3 knives.

Loader: Barko Model 160 hydraulic knuckle boom loader, with G17-G-53 power unit.

Unit has hydraulic powered hood, stabilizers, infeed trough and compression rolls. Discharge spout has a powered swivel, controlled from the operator's cab. It is equipped with its own air compressor, air receiver tank and air wrench, to provide for rapid knife changes. It is also equipped with a dirt separator.

This chipper has very adequately handled all the birch available on the cutover both standing and felled and has provided a uniform chip. The dirt separator has removed all twigs that could cause problems in the mill pneumatic transport system. Knife changes are easily done in 10 minutes, and the frequency depends on the cleanliness of the full trees as fed in on the infeed conveyor. Mechanical problems have been of a very minor nature. A reliable, sound machine.

7.1.3 - *Transportation*

The chips are blown into metal containers contained on the back of regular "pallet" trucks.

Containers are the regular type used in the International transportation of goods, in the standard 8 foot by 8 foot by 20 feet long, with double, sealed doors on the back end. An extra container was fabricated locally from plywood and aluminum, to try and get a larger pay load of chips per trip. The increase was marginal.

Trucks used were the usual diesel powered, pallet type trucks used to transport 4 foot pulpwood. They normally back into a landing and by elevating two hydraulically operated rails, allow the fabricated pallet to skid off onto the ground. They normally carry 6½ cords of 4 foot pulpwood per trip. For chip transportation, the freight

7.1.3 Cont'd.

containers were bolted to the pallet, and are handled the same as a load of pulpwood, except that with a loading time of 10 minutes, it is not necessary to drop the pallet onto the ground. The chips are blown into the container through an opening in one of the rear doors. Three trucks were adequate to handle the volume of chips produced.

7.2 - *PHASE II - SYSTEM II*

7.2.1 - *Harvesting*

The objective in Phase II was to integrate pulpwood and fuelwood operations, and it was necessary to select equipment which could deliver whole trees to roadside. Since the main source of fuelwood was in limbs and tops, it was imperative that trees be kept from contact with the ground to avoid contamination which would be detrimental to chipping and make the biomass unsuitable for burning. Therefore, the skidders which were used in Phase I operations could not be used in Phase II.

The equipment finally selected was a Koehring Feller - Forwarder, Model K3FF. This unit was equipped as follows:

- Multiple tree shear felling head 24" c/w 9" diameter shear cylinder
- Wheelbase 28"
- Engine Cat Diesel 330 6TA
- Engine safety shut down system actuated by low engine oil pressure, high collant temperatures, low hydraulic oil level and high pump drive gear box temperature
- Engine coolant low level indicator mounted in cab
- Operator's cab, insulated with heater and defroster fans
- Differentials - high traction in front and rear drive
- Planetary final drives 8:6:1

7.2.1 Cont'd.

- Steering cylinders 6" diameter
- Dump cylinder 8" diameter
- Bunk sides (filled in bottom and partial side plates)
- Fire suppression system in engine compartment consisting of two only manually actuated 30# dry chemical extinguishers, nitrogen powered, heat sensors, nozzles and alarm bell
- Hydraulic oil cooler, separately mounted with thermostatically controlled hydraulically driven fan
- Hydraulic oil tank heater, electric, 3000 watt with 50' - 3 wire extension cord
- Engine coolant heater 1500 watt
- Extreme service bottom pans
- Tire chains 5/8"

The above equipment was operated on a two shift basis.

7.2.2 - *Processing*

The equipment selected to process the whole trees at roadside was a Hahn Short Wood Harvester. This unit delimbs and tops the trees and recovers pulpwood in eight foot lengths. The residue left as limbs and tops is potential fuelwood.

The following are the particulars with respect to this equipment:

Dimensions

Length - 39'-3"
Width - 8' (travel configuration)
Height - 12'-8" (travel configuation)
Weight - 25,500 lbs.

7.2.2 Cont'd.

Drive System

Engine: GM 353 (std.): 78 Hp @ 2200 rpm
Axle: Franklin F-185, no-spin planetary
Propel Motor: 28.88 cu.in.
Brakes: Hydraulic disc/caliper type in drive line

Loader

All hydraulic; external gear/turntable bearing; dual hydraulic motor swing through 320' (approx.); 20 ft. boom with 6" bore cylinders on Main and Jib
Grapple: 1/3 cord, bypass

De-Limb

Carriage: Driven with two hydraulic cylinders
(a) Instroke (feed): 10,000 lbs. force at 5.7 ft. per sec.
(b) Out Stroke (de-limb): 19,600 lbs. force at 2.9 ft. per sec.

Capacity

(a) Hold down will accept up to 23" dia. stem
(b) Unit will de-limb from 20" to 3" top

Shear

78,560 lbs. force at 1.37 ft. per sec.

Fuel Capacity

Approximately 55 gallons

Hydraulics

Carriage: Driven by two hydraulic cylinders
Man Pump: Dual Control - 56 gpm - 37 gpm - 28 gpm triple gear

Pump Drive

Single place, disconnect clutch

Filtration

Four 10 micron spin-on filters

7.2.2 Cont'd

Oil Reservoir

(a) Capacity: (1) System: 110 gallons
(2) Tank: 65 gallons
(b) Oil: ATF

Systems Pressure

2000 psi

Electrical

12 volt DC

Dual cab controls for two man operation.

7.2.3 - *Chipping*

The nature of the material to be chipped (limbs and tops) made it necessary to carefully select a chipper as it was thought to be the key to the success of the Phase II trials. The unit selected was a Bruks chipper, Model 1000 CT. It was equipped as follows:

- Drum chipper infeed opening (16.5 x 22.0 inches)
- Hydraulic, upward folding
- Infeed chain table, for chipping small material such as limbs, tops, short ends, etc.
- Infeed spout with hydraulic lower table roll for whole trees
- Chip discharge tube
- Deutz air cooled V-8 Diesel engine F8L413F developing 214 Hp at 2300 rpm
- Twin disc PTO clutch
- V-belt transmission
- 300 litre fuel tank
- Hydraulic system complete with tank and pump

The above unit was mounted on a low bed trailer as shown in Photos 24, 25 & 28.

8.0 THE HARVESTING & CHIPPING OPERATIONS

8.1 - *PHASE 1 - SYSTEM 1*

The harvesting system selected for Phase 1 of the trial was similar to the major part of our pulpwood harvesting operation. This consisted of manual felling and full tree skidding to a central landing. The trees were skidded using three Timberjack 450 cable skidders and delivered to a Morbark 22 Chiparvester. A schematic of the system is shown in Fig. 6

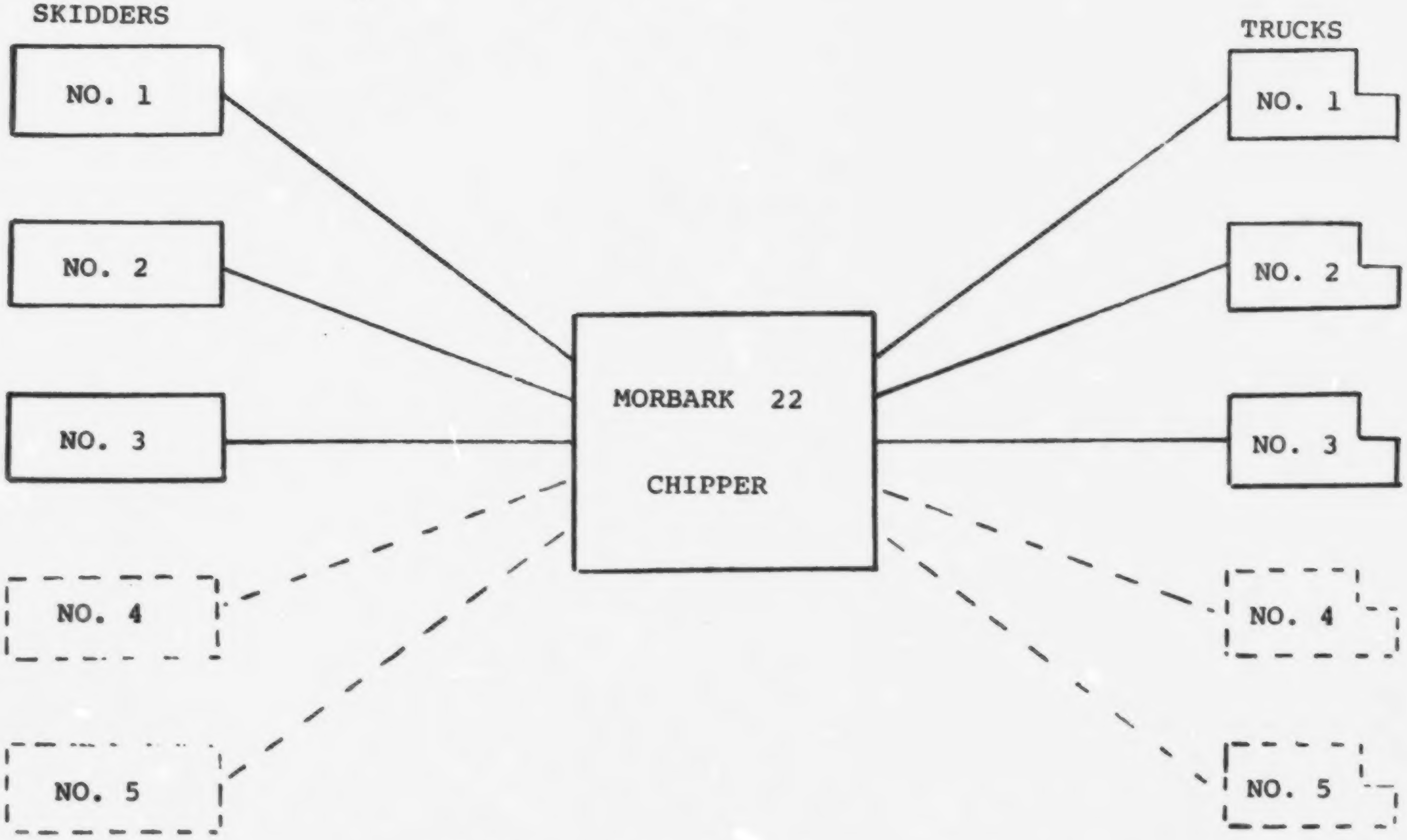
8.1.1 - *Harvesting*

One cutter worked with each skidder. The cutter felled the trees and assisted the skidder operator to hook up the load. (Photo 5, 6, & 7). The original intent was to utilize the residual birch left on the cutover after pulpwood harvesting. However, since the birch was scattered, the skidders had to make several stops to make up a "load". To increase production, the operators began to be less selective and picked up all wood, hardwood or softwood, which was large enough and sound enough to hold together until it could be skidded to the landing. This had the added benefits of reducing time to pick up a load, increased yield per acre, and did a much better job of cleaning up the site. The latter is particularly important if planting of the area is necessary.

Cut layout was not difficult for the skidder crews. The area had been logged for pulpwood in 1978. Skid trails from that operation were used as block boundaries for the clean-up operation. (Photo 8). Skidding distances were as long as 1200 meters but averaged 500 to 600 meters.

Skidders, (Photo 9), delivered the trees to the chipper on the side opposite the chip discharge spout. (Photo 10). This allowed the skidder operators to unhook their loads without interfering with chipper operation and the loading of chip vans. This is also where the knuckle boom loader proved to be much more effective than the straight sliding boom loader. The chipper operator picked up trees deposited by the skidder on one side of the chipper and carefully piled them, or "cold decked" them,

BIOMASS HARVESTING SYSTEM - PHASE I


SKIDDERS
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
MORBARK 22
CHIPPER
TRUCKS
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5

Shows the main elements in a Biomass Harvesting System.

Dotted lines indicate expansion capabilities of System.

Figure 6

8.1.1 Cont'd.

on the opposite side just to the rear of the discharge chute. (Photo 11 & 12). As many as 10 truck loads could be stockpiled for chipping in this way which made the operation more flexible. Skidders were able to keep working without danger of being blocked. Trucks also were independent of skidders and were not kept waiting for skidders to bring in their loads, as long as a stockpile was maintained.

The above description was for a summer - fall operation but a similar system was used to harvest the pure hardwood stands during winter operations. The only additional equipment used was the addition of a tractor to open skidder roads and do other snow clearing activities around the harvesting and chipping site.

8.1.2 - *Chipping*

When the wood arrived at the landing, the chipper utility man trimmed off any big branches or crooked butts that might cause chipper feeding problems. These parts were put through the machine separately after the main part of the tree had been chipped. This requirement was the exception rather than the rule but was necessary to keep the chipping operation running smoothly.

The chipper was capable of chipping trees up to a diameter of 55 centimeters (22 inches). The loader picks up one or more trees (Photo 11) depending on size and places them on the infeed deck, making sure that the butts are engaged with the infeed rollers and feeding freely. (Photo 13). Care should be taken to prevent force feeding if jamming occurs. A good operator can feed the chipper at good production rates and keep jamming to a minimum. Production rates for the chipper when loading a truck were as high as 89 green tons/hour and averaged 52 tons/hour. This indicates how much potential excess capacity the chipper has compared with the rest of the system.

The Morbark chiparvester (Photo 12) was equipped with three chipping knives which required changing somewhere between 20 to 100 tons of production.

8.1.2 Cont'd.

The frequency of knife changes was almost exclusively determined by the amount of mud, etc., on the wood being chipped. Wet weather gave the most problems in this regard. A knife change took approximately ten minutes and was scheduled mainly when trucks were transporting chips to the Mill so as not to interfere with production. Knife sharpening was done at the Mill and spare knives were kept on hand at the chipper.

The Morbark chiparvester is a portable machine although it is not self propelled. It is basically a trailer and is towed by means of a fifth wheel hook-up. In this particular operation, an old Mack tractor truck equipped with a fifth wheel was used to move the chipper from landing to landing. As this area had recently been harvested, the existing road network was utilized. Distance between landings varied between 500 to 1000 metres. To move an operation from one landing to another and have the system back into production required approximately 1 - 2 hours. There were only four such moves during the trial.

The chipper was equipped with lights which permitted after shift servicing and repairing of equipment. Chips could also be produced, if required, as long as a supply of wood was available from the "cold deck". A full time mechanic was not employed but services were available on call from a skidder garage approximately three miles distant.

Production and time study data were recorded by a technician hired to analyse the various system components. The various production data, availability and utilization of skidders and the chipper are outlined in Table 8.

This information clearly illustrates the low utilization of the chipper and indicates the significant production increase possible on this unit. To increase production on the chipper, additional skidders and trucking capability are required. In the particular circumstances at Bowater Newfoundland, the limitation on increasing production in this manner was the capability of the mill boilers to handle solid fuel. A production of 120 tons of chips per day or 600 tons per week was about the capability of the boilers under present conditions to burn chips. The chips were additional to the 2170 tons/week

TABLE 8: PRODUCTION SUMMARY FOR THREE TIMBERJACK 450 CABLE SKIDDERS AND ONE MORBARK 22 CHIPARVESTER WHILE WORKING ON BOWATER - ENFOR TRIAL - July 5 - Nov. 15, 1981

Item	Skidders	Chipper
Scheduled Machine Days	254.0	96.0
Scheduled Machine Hours	2032.0	812.0
Available Machine Hours	2011.0	701.25
Availability	99%	86%
Productive Machine Hours	1986.0	346.0
Utilization	98%	43%
Tons Produced	8991.5	8991.5
Tons Per Day Per Machine	35.2	100.0
Tons Per A.M.H.	4.4	12.8
Tons Per P.M.H.	4.5	26.0
Truck Loads Produced	-	933.0
Truck Loads Per Day	-	10.0
Truck Loads Per A.M.H.	-	1.3
Truck Loads Per P.M.H.	-	2.7
Tons Per Truck Load	-	9.6

8.1.2 Cont'd.

of bark available at the Mill site. The cost of chips could be significantly reduced if the full productive capacity of the chipper was utilized.

The above description was for the summer - fall operation but was almost identical for the winter system. Because of the pure hardwood stand, tree size was significantly smaller with smaller crowns so that it was not necessary to trim branches and interference with feeding was minimal. It was not necessary to move the chipper at any time during the winter trials as the tons of biomass per acre were approximately four times as great in the pure hardwood stands which meant skidder hauls were shorter and the acres harvested correspondingly reduced.

8.1.3 - *Manpower*

The total manpower employed in the operation for approximately 120 green tons per day is as follows:

1. 3 - Cutters
2. 3 - Skidder Operators
3. 1 - Chipper Operator
4. 1 - Utility Man
5. 1 - Technician
6. 1 - Foreman
7. 3 - Truckers
8. 1 - Mechanic - Part Time

Total 14

For a normal operation, the technician is not required but a foreman would be required full time.

8.2 - *PHASE II - SYSTEM II*

The harvesting system selected for Phase II of the trial was an integrated pulpwood - fuelwood system. The main components of the system were:

1. a Koehring feller forwarder (Photo 17)
2. a Hahn shortwood harvester (Photo 22), and
3. a Bruks chipper (Photo 28).

The equipment for both pulpwood harvesting and fuelwood processing was unlike any previously operated by the Company with the exception of the Hahn processor with which there was limited experience. This system delivers the whole tree to roadside without it having previously been in contact with the ground. This enables delivery of biomass in the form of limbs and tops, free of grit and rocks. Contamination of limbs and tops would seriously affect its usefulness as a fuel. At roadside the trees are delimbed, topped and cut into eight foot pulpwood by the Hahn processor. After processing the residues (in the form of limbs, tops and hardwoods) were left at roadside where they were picked up and fed to a Bruks disc chipper. A schematic of the chipping rig is shown in Fig. 7

8.2.1 - *Harvesting*

To cut and deliver whole trees to roadside the Koehring Feller-Forwarder was used. (Photo 18). This machine is equipped with a cutting, accumulating head. After a number of trees are cut, they are dropped into a rack at the rear of the machine. The rack (Photo 19) can accomodate 15 cubic meters (6¼ cords) of solid wood and the machine can cut and deliver to roadside 5 to 6 loads per shift. Because the cost of this piece of equipment is in excess of one-half million dollars, it is necessary to operate more than one shift to obtain a level of production that will justify the cost involved. The Koehring was operated for two shifts, 8 a.m. to 4 p.m. and 4 p.m. to 12 a.m.

The Koehring delivered its load to crawler tractor prepared sites along the main access road. (Photo 19, 21, & 23). These prepared shoulders were necessary to accommodate the subsequent processing

Sketch Showing Chipper & Operating Conditions

PHASE II

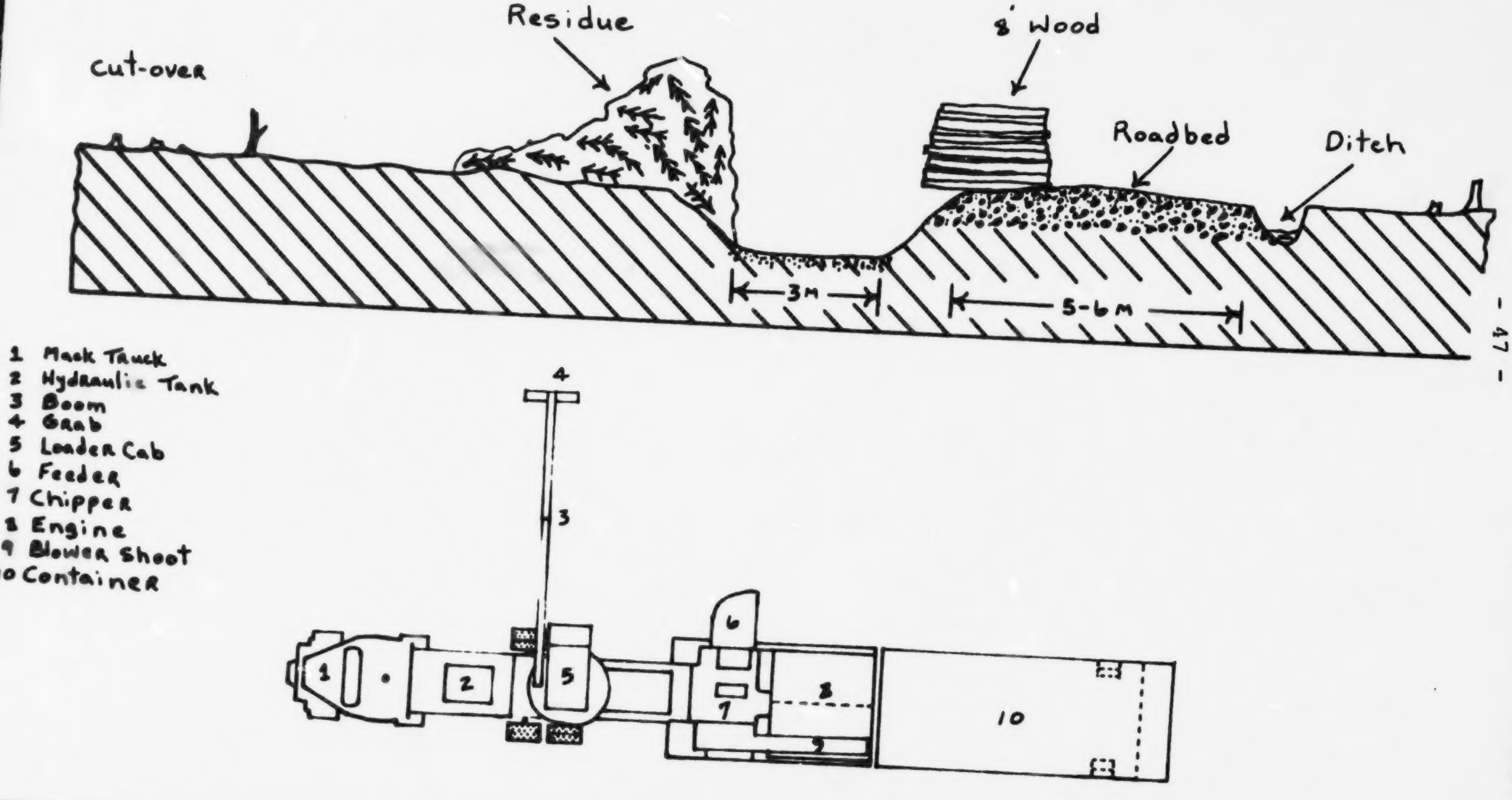

Residue
8' Wood
Cut-over
Roadbed
Ditch
3M
5-6M
1 Mack Truck
2 Hydraulic Tank
3 Boom
4 Grab
5 Loader Cab
6 Feeder
7 Chipper
8 Engine
9 Blower Shoot
10 Container
4
3
1
2
5
6
7
8
9
10

Figure 7

8.2.1 Cont'd.

by the Hahn Shortwood Harvester. (Photo 22 & 23). Loads were spaced 3 - 4 meters apart. (Photo 21). This spacing was found necessary to separate residue and unprocessed trees and improved the operation of the total system.

To obtain detailed information relating to total biomass and the recovery of pulpwood and fuelwood, a trial block was laid out and divided into Sections A & B for a more intense study.

Trees from each section were kept separate. Because space was limited at Section A, loads were piled on residue from the Hahn processor. This would later cause problems at the chipping stage but could not be avoided.

Harvesting at Section A started on October 4th, 1982 and finished on October 13th, 1982. Section B was started on October 14th, 1982 and finished on October 20th, 1982. The Hahn processor worked with the Koehring Feller-Forwarder but was not able to keep ahead of the Koehring. Both systems worked on a two-shift basis but the Hahn required nine additional shifts (4½ days) to complete the processing for the two trial blocks.

One of the objectives of the Phase II operation was to assess the production matching capabilities of the total system - Koehring, Hahn and Bruks chipper. If either unit is under or over capacity with respect to the other, the total system's efficiency is compromised. This will be discussed more fully later in the report.

The harvesting phase of the system operated well with the only negative aspects being site disturbance by the large tires which formed ruts. There was also some fibre loss from breakage and high stumps. Although it is obvious that a harvesting machine such as the Koehring has limitations with respect to terrain and ground conditions, it performed reasonably well under less than ideal conditions. Wood is generally small in the Glide Lake area as harvesting was carried out to salvage budworm damaged stands. Under normal conditions, this forest would not have been harvested for another 20 to 25 years, and trees would be correspondingly larger. The soft nature of much of the terrain also mitigated against the most efficient operation of the Koehring.

8.2.1 Cont'd.

The data related to harvesting is shown in Table 9.

8.2.2 - *Processing*

Processing in this content is the recovery of 8 foot pulpwood from the whole tree, the removal of limbs and tops and storage of this residue in rows for chipping into fuelwood.

As soon as the Koehring had delivered 4 - 5 loads, the Hahn started processing. (Photo 22 & 23). The height of the piles presented some problems in that trees were difficult to separate. This caused top and stem breakage especially with dead fir trees. This slowed the production of pulpwood but left more residue for fuelwood. As the Hahn proceeded from pile to pile, the residue was placed in rows along the shoulder. Hardwoods (mainly birch) and trees too small for processing were also placed in the rows.

At the planning stages of these trials, concern was expressed that recovering hardwoods and separating them at the processing stage would seriously interfere with pulpwood production. Unfortunately the percentage of hardwoods was quite low on the trial blocks so that it was not possible to fully evaluate the effects of this interference. However with the limited experience that was available, it does not appear that this should be a major concern. As hardwood component increases, there will be some negative effects on pulpwood production and positive effects on fuelwood production. Longer trials on a variety of sites are necessary to quantify these assumptions.

Although trees were delivered to roadside free of contamination (Photo 20), there was some contamination of residue at the processing stage. This occurred as trees were being fed through the delimbing knives. (Photo 22). During this process, the overhung tops came in contact with the roadbed and picked up grit and gravel. On wet days the problem was multiplied. After a time, contamination decreased as debris from the shear and delimbing knives provided ground cover. There was also potential contamination when residue is close to the ground and the grab occasionally picks up rocks and gravel. Another source of contamination was from dust drift. Residue left for a period of time could exhibit abrasive characteristics which adversely affected chipper knives.

8.2.2 Cont'd.

There were a number of other points related to the processing phase, such as frequent breakage in dead fir and fibre loss as a result of processing eight foot lengths instead of four foot lengths. These losses are related to pulpwood loss but actually increase residues for fuelwood. Although breakage of dead fir increases due to entrappment in the piles and the mechanical nature of the system, breakage is partly due to loss of moisture and decrease in resiliency of the diseased, dead wood. This loss for fibre production may be beneficial from the perspective of paper quality although it does increase pulpwood costs. The loss of pulpwood in tops that were left because the upper end is too small in diameter is common to all eight foot pulpwood operations. Thus tops which could produce a four foot length of pulpwood had to be left because the operation required an eight foot length of pulpwood. This however is a positive feature of the pulpwood - fuelwood system as at least the fibre is recovered for burning, instead of being wasted as is the case when only eight foot pulpwood is being harvested. Fibre losses also occur if two trees of different sizes are processed together. Operator care can minimize these losses.

The Hahn shortwood processor operated two eight-hour shifts but could not match the production of the Koehring Harvester. For a number of reasons, which will not be detailed, production was below what has been achieved with other units in other locations. Although the mismatch of production on these units is of concern when evaluating the total efficiency of the system, operating personnel believe production of the Hahn can be increased. Processing data for this unit can be seen in Table 9.

8.2.3 - *Chipping*

The chipping function of these trials was the key to whether or not limbs and tops from softwoods can be economically recovered as fuelwood. In Phase I, the key function was the recovery and transport of residual hardwoods to roadside. In Phase I, the chipping operation proved to have capacity well in excess of the rest of the system. In Phase II, the chipping operation set the rate at which biomass could be recovered and determined the economics of the process.

TABLE 9

SYSTEM ANALYSIS - PHASE II - SYSTEM II

TRIAL BLOCK

KOEHRING K3FF	Section A	Section B	TOTAL
Operating Period	Oct. 4-13/82	Oct. 14-20/82	Oct. 4-20/82
Stand Area	19 acres	15.1 acres	34.1 acres
Shifts worked	15	9	24
Loads produced	77	47	124
Merchantable Trees	9,749	6,626	16,375
Productive hours	101	65	166
Cords produced	417.5	345.5	763
Cords/Acre	22.0	22.9	22.4
Trees/Cord	23.4	19.2	21.5
Cords/Koehring load	5.4	7.4	6.2
Cords/shift (8 hrs.)	27.8	38.4	31.8
Cords/day (2 shifts)	55.6	76.8	63.6
HAHN PROCESSOR			
Operating period	Oct. 4-15/82	Oct. 15-25/82	Oct. 4-25/82
Shifts worked	18	15	33
Cords produced	417.5	345.5	763
Productive hours	128	90	218
Cords/shift (8 hrs.)	23.2	23.0	23.1
Cords/day (2 shifts)	46.4	46.0	46.2
BRUKS 1000 CT			
Operating period	-	-	Oct. 14-19/82
Shifts worked	16	12	28
Containers produced	40	31	71
Tons produced	213.2	165-2	378.4
Productive hours	49	42	91
Koehring loads/container	1.9	1.5	1.7
Tons/acre	11.2	11.0	11.1
Containers/acre	2.1	2.1	2.1
Tons/day (1 shift)	13.3	13.8	13.5

8.2.3 Cont'd.

The chipper selected for these trials was a Bruks 1000 ct. (Photo 28). The chipper was mounted on a low bed trailer and was hauled by a Mack truck. (Photo 24). Unfortunately the system had limited mobility due to ground conditions and weight distribution. This is especially true when containers were partly loaded. In most cases, a skidder or tractor was required to move the system. In addition to the chipper (7), Fig. 7, the mobile unit contained a grapple loader (5), and a chip container (10). Other parts are shown in Fig. 7.

The initial trial period was used to familarize the operator with the new techniques and to work out the bugs in the system. During this period, there were a number of mechanical problems which included the following:

- mechanical problems with the Mack truck
- frequent breaking of the swing chain on the loader
- leaking and breaking hydraulic hoses

Because of these difficulties and the experience gained in the initial trials, it was decided on October 1, 1982 to remove the unit from operation. It was forwarded to Brake's Cove Repair Shop at Corner Brook for repairs and alterations and rearrangement of the loader and boom. This was to prove satisfactory and increased the range of the grapple and reduced the number of times the system had to be moved. The system went back into operation on October 14th. Prior to October 1st, the system had not been working in close proximity to the Koehring and Hahn but was picking up residues left by the Hahn during the winter and early summer of 1982. After October 14th, the chipping unit began chipping residues left from trial blocks A & B as noted under the harvesting section.

The chipper proceeded behind the Hahn processor. Before the chipping rig could begin, the working area had to be cleaned up behind the Hahn by a tractor. This was necessary because the length (18 meters) and weight distribution of the rig made mobility on the off-road site very difficult. The services of a skidder or tractor was also required for road preparation and for snow clearing towards the end of the trial.

8.2.3 Cont'd.

The Bruks 1000 ct is a drum type chipper, (Photo 28), with special infeed features to handle the softwood limbs and tops. Although the infeed system, (Photo 25, 26 & 27), was disappointing with regard to production rates, this chipper appears to be one of the best on the market to cope with the extremely difficult raw material to be processed. If biomass harvesting of softwood limbs and tops is to become economical in this part of the world, then improvements to the infeed mechanism are of the highest priority. Production rates can only be increased significantly if the grapple, (Photo 24 & 25), is used to pick up material and drop it into the infeed conveyor and then immediately return to pick up more material. At present too much time is lost because the grapple is trying to assist the infeed mechanism to feed material to the chipper. (Photo 27). The actual chipping time is about one half the actual load time. The higher the proportion of tops and broken stems, the greater the capacity of the chipper. This material feeds more easily into the chipper as well as having a higher weight per volume when compared with limbs.

Two other factors significantly influencing chipper production were rig mobility and container transfer. The chipper rig with the container mounted in the carrying rack was 18 meters long. (Photo 24). A lot of space was required to manoeuver the rig into a chipping position. With a container partially loaded, the weight was concentrated on the rear trailer axles. This rendered the drive axles of the truck practically frictionless. Even with a skidder on stand-by, there were times when a tractor was required to unstick the rig. During wet weather, water mixed well with the loomy soil to produce a "muck" that provided no traction.

Box transfer also proved to be very inefficient. It was not uncommon to be waiting one hour for a truck after a box had been loaded. With a truck on stand-by, it still required 20 - 30 minutes to transfer boxes. Often transfer was hampered by the tilt of the lowbed trailer, muddy conditions or debris from the chipper infeed chains.

8.2.3 Cont'd.

Having one truck to transfer a box was a slow process. When the truck arrived with an empty container, it had to be immediately off-loaded on the ground. The full container on the trailer rack was then off-loaded and the empty container picked up and loaded on the trailer rack. The chipper was again ready for production but the truck had to once again pick up the full container before it could be transferred to Corner Brook. In the Phase I trials, the chip loading time was so short (11 minutes) that a minimum of chip transport time was lost by keeping the container always mounted on the truck. In Phase II because of the longer chip loading time, it was necessary to separate the container from the truck to mazimize the time a truck is transporting chips. However, it is obvious from the above procedure that the alternative is not effective and some other system to speed up container transfer or a new approach is required.

If the chipper rig could be made more mobile and include a self-dumping container, it might be possible to eliminate much of the lost time involved in the above two items. These features, with an improved infeed, are the major areas for increasing the production from the chipping stage of the system.

With the chipper rig in position and a good supply of residue on hand, a container could be loaded in about one hour and fifteen minutes. The actual chipping time was about one half the load time. The remainder of the time was to pick up residue and get it to feed properly into the machine.

Contaminated material was rejected if noted by the operator in an attempt to protect the knives and prolong the time between knife changes. It took from 20 to 30 minutes to change a set of knives. Approximately four to eight containers of chips could be processed between knife changes. Of the original supply of six sets of knives, only 3½ sets were left at the end of the trial. Two and one half sets were damaged beyond repair by debris and rocks and the remaining knives were reduced as a result of grinding so that it was more difficult to set up the knives in the chipper. This indicates severe knife usage when it is considered that less than 700 tons of biomass were produced.

8.2.3 Cont'd.

Other problems as a result of wear and tear or contamination were:

- broken main pin in the boom of loader
- water and dirt in the fuel
- shortage of sharp knives
- engine overheating

Another factor which slowed production was the fuel-up time. In some cases, the chipper ended up working between the pulpwood and the residue, (Fig. 7). Because of this, it was impractical to move the chipping rig to the fuel so the fuel had to be moved to the chipper by drums. Even when travel to fuel was practical, it required travelling up to a mile beyond the fuel depot to get turn around space. Since the chipper could be fed from one side only, the rig had to again travel extra distance on its return to the chipping site to find turn around space so it could be properly positioned.

Various attempts were made to fill the 8'x8'x20' containers to capacity but this was not always possible. Doors were altered, a baffle was tried at the end of the blower shoot, but still it was not possible to completely fill the containers. One of the restrictions of this particular chipper is the low velocity of material leaving the blower chute. If larger sized containers were used, an auxiliary blower would be necessary to give the required velocity. The manufacturers will provide this addition if required. The blower was also hampered by improper box tilt or by extremely wet or dirty residues. On average, containers were 85% full.

A short trial was made feeding only white birch to the chipper. This trial pointed to a number of problem areas. The infeed drum had difficulty with the whole tree when crown branching existed. Continuous chipping of birch appeared to slow down and labour the chipper. These conditions existed even though the birch was small (4 to 8 inches). This could presumably be corrected by installing higher H.P. drives which are available from the manufacturer.

8.2.3 Cont'd.

The key to success with processing limbs and tops is the rate at which material can be fed to the chipper, or use of other equipment (shredder, etc.) to reduce the material to a size suitable for handling and burning. A machine designed to accept material from the top where gravity can asset the feed may have some possibilities. A chipper may not be the best equipment for reducing the size of limbs and tops. Something less sensitive to foreign material would be preferrable. In designing for top loading, the height of opening must not be too high or it will complicate and restrict the effectiveness of a conventional grapple. Although others may have more success with a similar system, we believe new approaches are necessary if recovery of limbs and tops as a source of solid fuel is to gain wider acceptance.

Photo 1 - *SYSTEM I*

Photo 2 - *SYSTEM I*

Photo 3 - *SYSTEM I*

Photo 4 - *SYSTEM I*

Photo 5 - *SYSTEM I*

Photo 6 - *SYSTEM I*

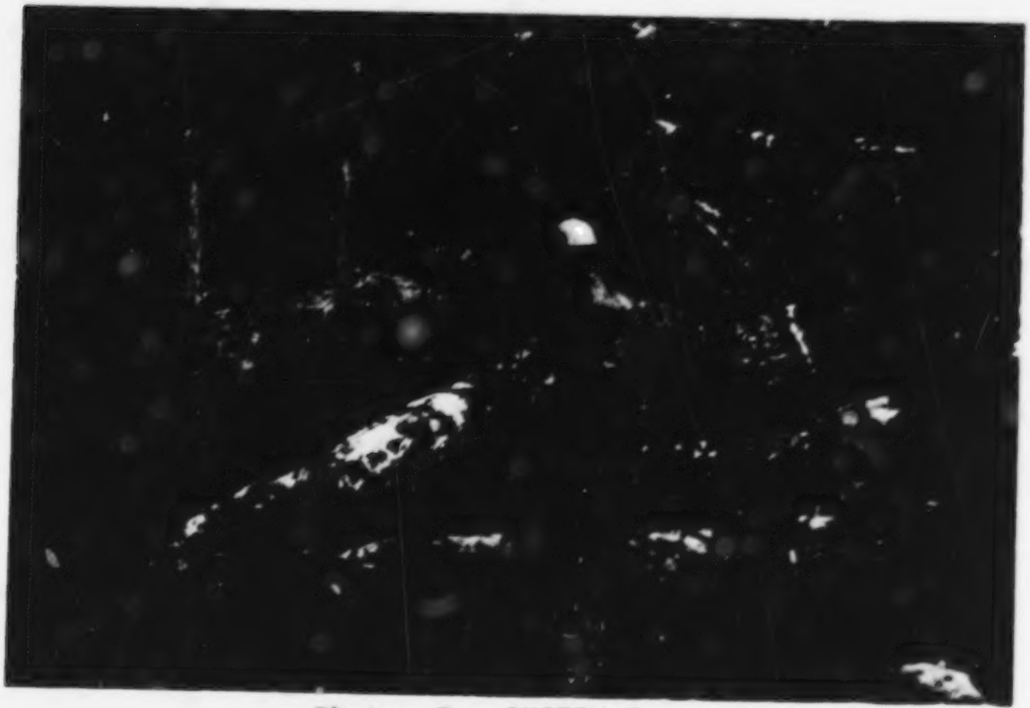


Photo 7 - SYSTEM 1

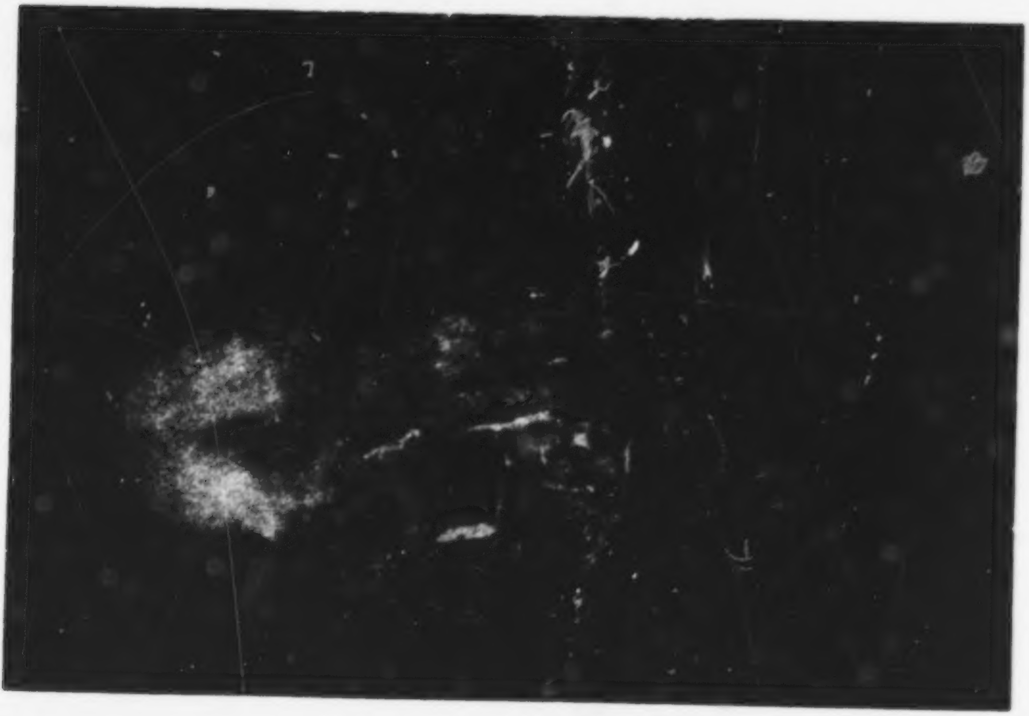


Photo 8 - SYSTEM 1

Photo 9 - *SYSTEM I*

Photo 10 - *SYSTEM I*

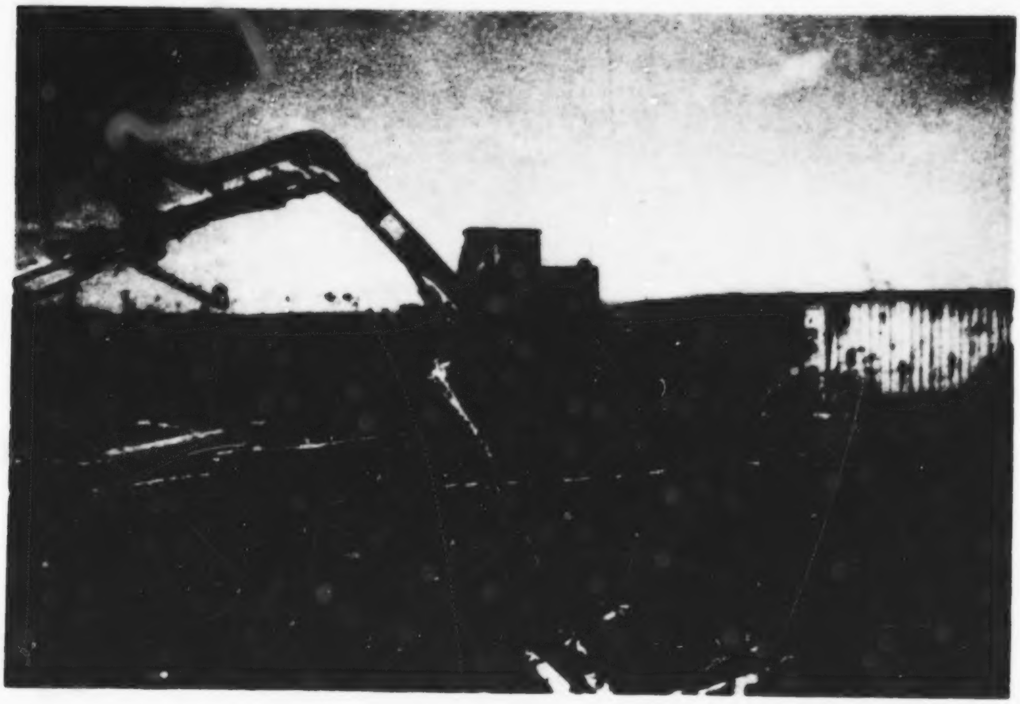


Photo 11 - *SYSTEM I*

Photo 12 - *SYSTEM I*

Photo 13 - *SYSTEM I*

Photo 14 - *SYSTEM I*

Photo 15 - *SYSTEM I*

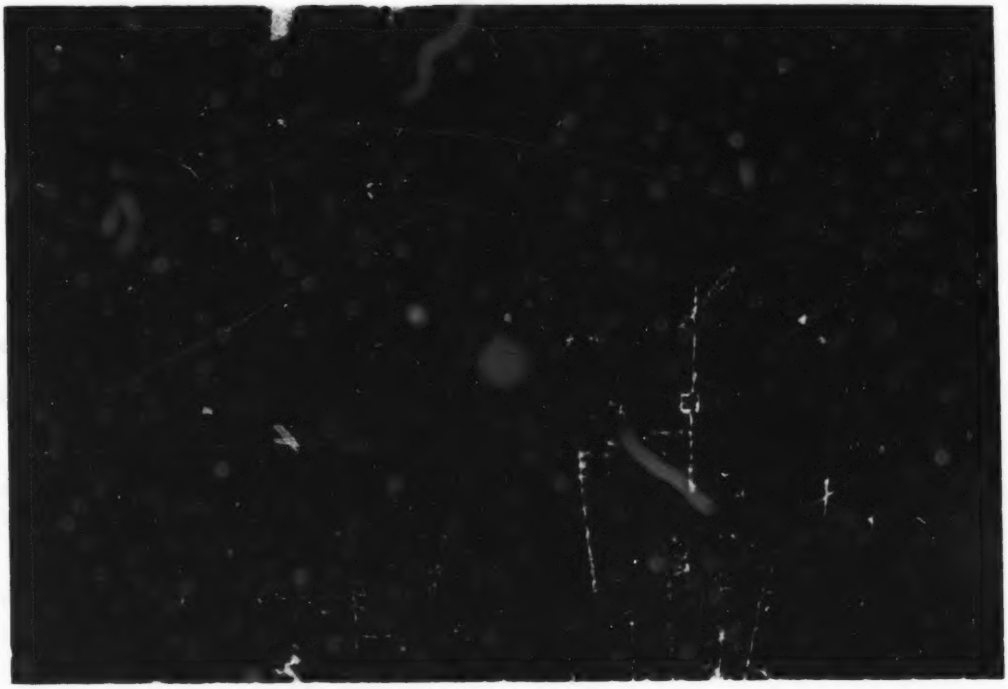


Photo 16 - *SYSTEM II*

Photo 17 - *SYSTEM II*

Photo 18 - *SYSTEM II*

Photo 19 - *SYSTEM II*

Photo 20 - *SYSTEM II*

Photo 21 - *SYSTEM II*

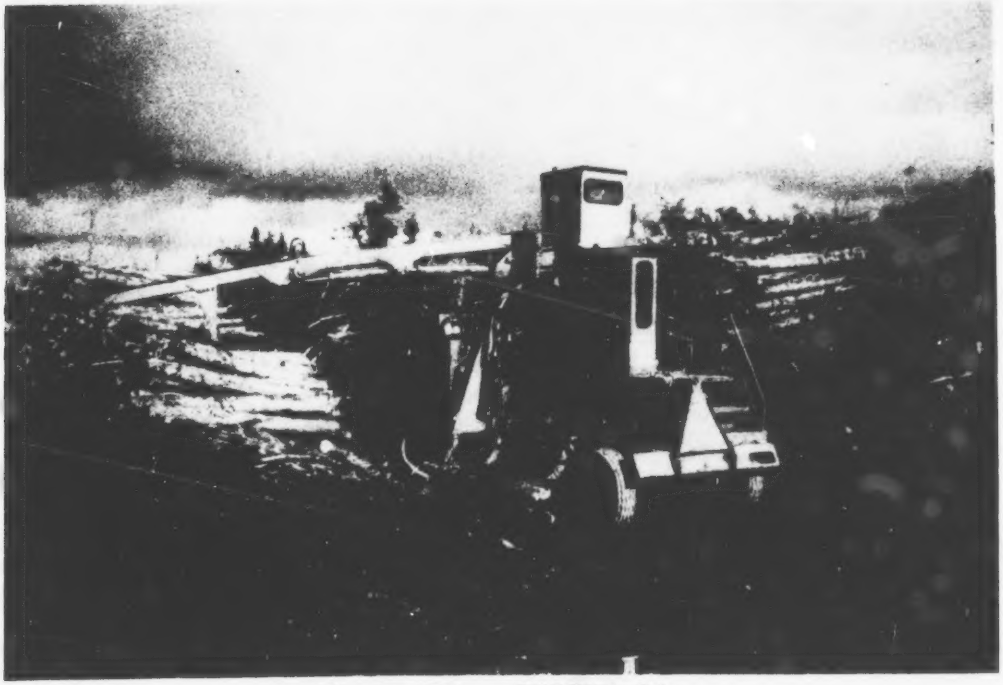


Photo 22 - *SYSTEM II*

Photo 23 - *SYSTEM II*

Photo 24 - *SYSTEM II*

Photo 25 - *SYSTEM II*

Photo 26 - *SYSTEM II*

Photo 27 - *SYSTEM II*

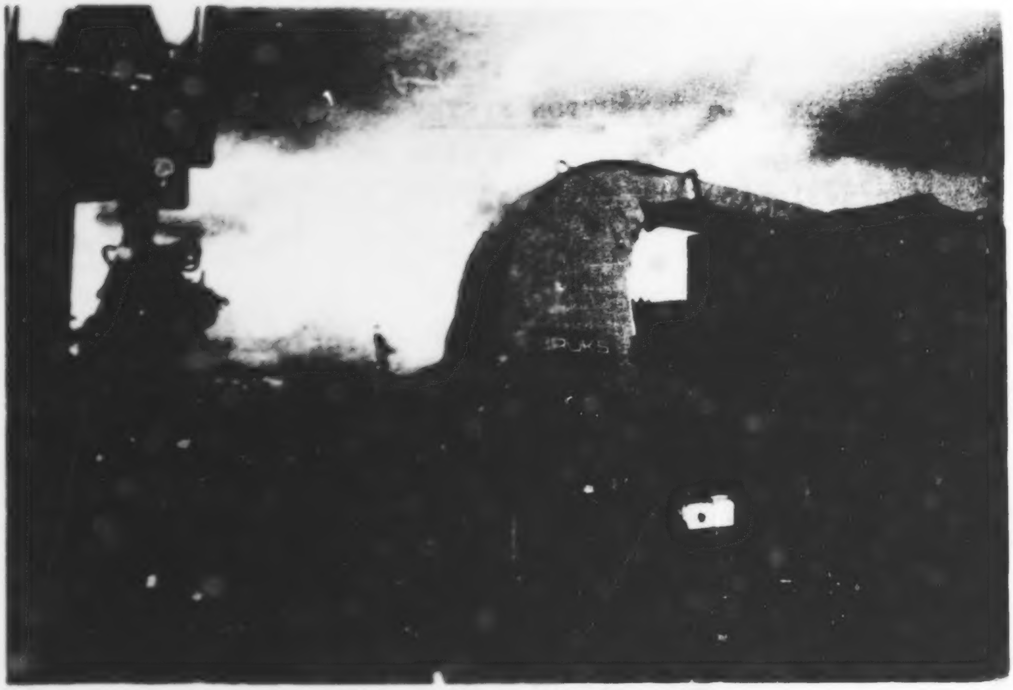


Photo 28 - SYSTEM II

Photo 29 - SYSTEM II

9.0 TRANSPORTATION & DISTRIBUTION SYSTEM

In designing the trial systems for burning of forest biomass, one of the objectives was to utilize existing systems where possible and avoid large capital expenditures that could prove obsolete if the trials were unsuccessful. In this connection, the transportation system chosen was a modification of an existing system used to transport pulpwood from the same general area. Pallet trucks (photo 14) were used to transport chips from the chipper by adding second-hand freight containers measuring 20' x 8' x 8'. Although the capacity of these units was low, they had the advantage of being suitable for the steep roads and their self dumping feature required no assistance or special unloading facilities at the mill site.

9.1 - *PHASE 1 - SYSTEM 1*

In this system, trucks backed up to the chipper with the container in place and chips were blown into the container (Photo 11). The time required to load a container ranged from 6 to 11 minutes. Because of the relatively short loading time, there was no advantage in having spare containers located at the chipper site for loading when no trucks were available. More time is lost in unloading and picking up containers than is required to fill the containers directly from the chipper. Unfortunately, because of highway weight restrictions, it was not possible to completely fill the containers so that theorically it was possible to add 10%-15% more material if this restriction did not exist. The rate of production of the complete system was geared to boiler capacity and not chipper production or transportation facilities. This was not strictly true for the summer of 1982 when production was curtailed because only two trucks were operating most of the time. This again was indirectly tied to mill conditions as the uncertainty resulting from mill downtime made it difficult to commit to truckers the volumes to be produced which in turn made it impossible for a trucker to make the commitment required to finance his operation.

An individual truck could transport three and sometimes four loads per day from the harvesting site located approximately 45 km from the mill. Trucks were weighed at the Department of Highways weigh scales on their way to the mill and checked through the Mill Yard scaling station for record purposes.

9.2 - PHASE II - SYSTEM II

The trucking unit and container used to transport the chipped material for Phase II was identical to that used in Phase I. However, because of the longer loading time (75 mins.), it was necessary to separate the container and mobile unit during the chipping-loading stage. As previously noted, this in turn created other problems which made the transportation system for Phase II less efficient than a similar system for Phase I. Having the container mounted on the chipping rig decreased the mobility of the chipper but reduced stand-by time for the trucks. However, the system as operated was not satisfactory. What may be needed is a smaller self-dumping container, integral with the chipper that will be used to fill larger containers which are a part of the trucking system. Whatever the system, the chipper needs to be more mobile and because of the low chipper production, the containers to be trucked must be separated from the trucking rig if stand-by time is to be reduced.

Larger containers for trucking are a must as the low bulk density of the material being chipped makes the payload for smaller containers uneconomical. The same containers which carried 9.6 green tons in the Phase I trials could only carry 5.3 green tons in the Phase II trials.

Because of the problems associated with achieving an adequate production level, it was difficult to structure an appropriate trucking system. Since the same trucking units were used for pulpwood and chips, integration of the chip-pulpwood transportation systems was possible. However, the chip transport suffered at the expense of pulpwood. Trips were also made after regular hours so that an empty container was available for start-up each morning. A round trip from chipper site to Corner Brook required 2 - 2½ hours.

Based on chipper production, the truck requirements would have been best suited to one and one half trucks. To provide extra trucking was an unjustified expense under the chipper production rates experienced so that this aspect of the trial was less than satisfactory and overall contributed to the low production of the system.

9.3 - GENERAL

Trucks arriving at the mill both for the Phase I and Phase II systems, dumped their loads on a concrete pad, adjacent to an existing infeed bark handling facility. This facility is capable of receiving bark or wood chips in an outside storage area and metering the material to conveyors. The extraction and metering device is called a Wennberg parascrew. It consists of a rotating screw travelling along the ground parallel with the axis of rotation and feeding material as required towards one end of the screw where it is deposited on a conveyor belt. The quantity of material is controlled by the speed of the screw. The conveyors deliver the bark and wood chips to a Holmes feeder and blower which transports the mixture a distance of 400' to storage bins above Nos. 1 & 2 boilers.

The storage is a live bottom bin which consists of a series of screws which deliver the solid fuel to the downspouts where it falls by gravity unto the sloping grate of the furnace. The feeding of bark in this manner is less than satisfactory as there is a tendency for the bark to bridge and honeycomb so that delivery of materials is not uniform and boiler operation and efficiency is adversely affected. When chips are mixed with bark, the mixture feeds better, but still does not provide the uninterrupted feeding that is necessary to realize the full boiler potential.

In general, the introduction of chips into the existing bark handling system did not present any problems and did not require any new materials handling equipment. The system handled the additional 80 tons/day of chips along with the regular 310 tons/day of bark. Steam Plant personnel were firm supporters of the new wood chip fuel as it improved the operation of the two bark burning boilers.

10.0 RESULTS OF TRIAL

In this section, the results of the trials are reported to show the productive capacity of the systems under winter and summer conditions and to assess the cost of producing fuel from the forest. The oil equivalent value of the material is also determined.

Detailed cost and production data were recorded for each part of the harvesting, chipping and transportation operations. Weekly and monthly summaries of the data were reported as shown in Tables 10, 11 and 12.

Burning tests were carried out to provide a basis for estimating the oil equivalent value of the chips. These tests were only partly successful. A better estimation of the value of forest biomass was obtained from a comparison of records prior to burning chips, with the two-year period when chips were utilized.

Results are presented for biomass production and cost at each of five sites. Although production data is comparable between sites, cost data is not comparable. Costs are in 1981, 1982 and 1983 dollars, depending on the time of the trials and fixed costs and start-up costs are not always comparable between sites. Site costs are a guide and are generally higher than can be expected for an ongoing operation because of fewer operating days, high rental costs and other factors.

In Section 10.5, a more useful analysis of costs is presented and projected costs are more meaningful in the context of an ongoing operation.

The five sites for which production and cost data are recorded are as follows:

Site 1 - Phase I - System I - Summer/Fall Operation 1981

Site 2 - Phase I - System I - Winter Operation 1982

Site 3 - Phase I - System I - Summer/Fall Operation 1981

Site 4 - Phase I - System I - Winter Operation 1983

Site 5 - Phase II - System II - Summer/Fall Operation 1982

TABLE 10

BOWATER NEWFOUNDLAND LIMITED

ENERGY FROM WOOD FIBRE - WEEKLY PRODUCTION SUMMARY

PERIOD Aug. 23 - 29, 1981

	PERIOD	7054 SKIDDER	7055 SKIDDER	7056 SKIDDER	SKIDDER TOTAL	7781 CHIPPER TOTAL
Scheduled Mach. Hours	This Week	40.0	40.0	40.0	120.0	44.0
	To Date	200.0	232.0	304.0	736.0	319.5
Available Mach. Hours	This Week	40.0	40.0	40.0	120.0	36.75
	To Date	200.0	232.0	302.0	734.0	274.25
Availability	This Week	100%	100%	100%	100%	84%
	To Date	100%	100%	99%	100%	86%
Productive Mach. Hours	This Week	40.0	40.0	40.0	120.0	23.0
	To Date	200.0	230.0	296.0	726.0	123.0
Utilization	This Week	100%	100%	100%	100%	52%
	To Date	100%	99%	97%	99%	39%
Tons Produced	This Week	224.8	195.5	201.0	621.3	621.3
	To Date	955.3	973.5	1310.0	3239.7	3239.7
Tons X Sched. Mach. Hours	This Week	1798.4	1564.0	1608.0	4970.4	5452.2
	To Date	7642.4	7787.6	10487.2	25917.2	26904.9
Tons/Day	This Week	45.0	39.1	40.2	41.4	123.9
	To Date	38.2	33.6	34.5	35.2	84.2
Tons/AMH	This Week	5.6	4.9	5.0	5.2	16.9
	To Date	4.8	4.2	4.3	4.4	11.8
Tons/PMH	This Week	5.6	4.9	5.0	5.2	27.0
	To Date	4.8	4.2	4.4	4.5	26.3
Truck Loads Produced	This Week					66.0
	To Date					339.0
Truck Loads X SMH	This Week					580.0
	To Date					2874.9
Truck Loads Per Day	This Week					13.2
	To Date					8.9
Truck Loads Per AMH	This Week					1.8
	To Date					1.2
Truck Loads Per PMH	This Week					2.9
	To Date					2.8
Tons Per Truck Load	This Week					9.4
	To Date					9.6

TABLE 11

BOWATER NEWFOUNDLAND LIMITED

ENERGY FROM WOOD FIBRE - MONTHLY PRODUCTION SUMMARY

PERIOD Sept. 27 - Oct. 31, 1981

	PERIOD	7054 SKIDDER	7055 SKIDDER	7056 SKIDDER	SKIDDER TOTAL	7781 CHIPPER TOTAL
Scheduled Mach. Hours	This Month	200.0	200.0	200.0	600.0	221.5
	To Date	552.0	584.0	656.0	1792.0	710.0
Available Mach. Hours	This Month	199.0	194.0	200.0	593.0	195.75
	To Date	539.0	578.0	654.0	1771.0	610.25
Availability	This Month	100%	97%	100%	99%	87%
	To Date	97%	99%	100%	99%	86%
Productive Mach. Hours	This Month	194.0	188.0	196.0	578.0	98.0
	To Date	533.0	569.0	644.0	1746.0	297.0
Utilization	This Month	97%	94%	98%	96%	44%
	To Date	97%	97%	98%	97%	42%
Tons Produced	This Month	809.1	831.7	841.6	2482.4	2482.4
	To Date	2447.3	2517.5	2871.7	7836.5	7836.5
Tons X Sched. Mach. Hours	This Month	6472.8	6653.0	6732.8	19859.2	24679.7
	To Date	19578.4	20139.6	22973.6	62691.6	70626.8
Tons/Day	This Month	32.4	33.3	33.7	33.1	111.4
	To Date	35.5	34.5	35.0	35.0	99.5
Tons/AMH	This Month	4.1	4.3	4.2	4.2	13.0
	To Date	4.5	4.4	4.4	4.4	12.8
Tons/PMH	This Month	4.2	4.4	4.3	4.3	25.3
	To Date	4.6	4.4	4.5	4.5	26.4
Truck Loads Produced	This Month					258.0
	To Date					817.0
Truck Loads X SMH	This Month					2231.0
	To Date					7059.9
Truck Loads Per Day	This Month					10.1
	To Date					9.9
Truck Loads Per AMH	This Month					1.4
	To Date					1.3
Truck Loads Per PMH	This Month					2.6
	To Date					2.8
Tons Per Truck Loads	This Month					9.6
	To Date					9.6

TABLE 12

BOWATER NEWFOUNDLAND LIMITED

ENERGY FROM WOOD FIBRE - WEEKLY CHIPPER PRODUCTIVITY

PERIOD Aug. 23 - 29, 1981 MACHINE NO. 7781

DATE			S	M	T	W	T	F	S	TOTAL
Sched. Mach. Hours				9.0	8.0	8.0	11.0	8.0		44.0
AVAILABLE MACHINE HOURS	Productive Mach. Hours			5.0	6.0	4.0	4.0	4.0		23.0
	Non-Mech. Delay	Operation Delay		2.5	1.5	3.5	2.75	3.5		13.75
		Personnel Delay								
		In-Shift Moving								
	Total			7.5	7.5	7.5	6.75	7.5		36.75
DOWN TIME	IN-SHIFT	Active Repair		0.25			2.0			2.25
		Waiting Repair		0.25						0.25
		Waiting Parts								
		Knife Change		0.75	0.5	0.5	0.25	0.5		2.5
		Service		0.25						0.25
	OUT-OF-SHIFT	Active Repair					2.0			2.0
		Knife Change								
		Service								
	Total			1.5	0.5	0.5	4.25	0.5		7.25
PRODUCTION	Tons			120.9	165.6	114.5	120.3	100.0		621.3
	Tons X SMH			1088.1	1324.8	916.0	1323.3	800.0		5452.2
	Tons/Day			120.9	165.6	114.5	120.3	100.0		123.9
	Tons/AMH			16.1	22.1	15.3	17.8	13.3		16.9
	Tona/PMH			24.2	27.6	28.6	30.1	25.0		27.0
	Truck Loads			13.0	17.0	12.0	13.0	11.0		66.0
	Tons/Load			9.3	9.7	9.5	9.2	9.1		9.4
	Loads X SMH			117.0	136.0	96.0	143.0	88.0		580.0
	Loads/Day			13.0	17.0	12.0	13.0	11.0		13.2
	Loads/AMH			1.7	2.3	1.6	1.9	1.5		1.8
	Loads/PMH			2.6	2.8	3.0	3.2	2.8		2.9

10.1 - PRODUCTION - PHASE I - SYSTEM I

10.1.1 - Production - Site 1

This represents the initial trials by Bowater to produce forest biomass as an alternative source of fuel to replace Bunker "C". The trial period was from July 5th, 1981 to November 15th, 1981 and a progress report on this trial was published in June 1982 as ENFOR Project P-191.

The trial started slowly as equipment was set up and operators became familiar with new equipment, and new techniques were developed and assessed. The system started with only one skidder supplying the chipper. A second skidder was added after the second week and by the fifth week, the system was operating at the capacity that could be attained with three skidders. It was not possible to increase capacity of the system by adding more skidders as there was a limitation on the amount of solid fuel that the Mill boilers could use. The phased start-up gave Woods and Mill personnel an opportunity to gain experience in the harvesting, chipping, delivering and burning of new fuel. With all equipment operating after the fifth week, production was as high as at any time during the trial. Production remained relatively steady until the eleventh week when production was reduced because adequate trucking capacity was not available. With three trucks available after the fourteenth week, the system increased production but did not quite reach the high productions of August because of wet weather conditions. The project shut down on November 15th which coincided with the regular fall shut down of Woods operations. A total of 8991.5 tons was produced at Site 1.

TABLE 13 - *Production - Site 1*

Date	*Green Tons*
July 5 - 11	74.4
July 12 - 18	232.5
July 19 - 25	287.9
July 26 - Aug. 1	413.8
Aug. 2 - 8	431.6
Aug. 9 - 15	513.8
Aug. 16 - 22	664.4
Aug. 23 - 29	621.3
Aug. 30 - Sept. 5	655.3
Sept. 6 - 12	436.4 (4 days - Labour Day Shut)

TABLE 13 Cont'd.

Date	*Green Tons*
Sept. 13 - 19	596.2
Sept. 20 - 26	426.5
Sept. 27 - Oct. 3	390.9
Oct. 4 - 10	431.0
Oct. 11 - 17	589.3
Oct. 18 - 24	630.3
Oct. 25 - 31	440.9
Nov. 1 - 7	537.2
Nov. 8 - 14	569.8
Nov. 15 - 21	48.0 (1 day)
TOTAL	8991.5 TONS

An analysis of the production data in Table 13 indicates the following:

TABLE 13A

1. Average for 19 week period (includes start-up and periods when equipment not operating)	- 473 tons/wk.	- 94.6 T/D
2. Best 10 Weeks (all equipment operating)	- 592 tons/wk.	- 118.4 T/D
3. Best 4 Weeks	- 643 tons/wk.	- 128.6 T/D
4. Projected production (5 skidders and utilizing full chipper capacity)	- 985 tons/wk.	- 197.0 T/D

The ten week operating period, producing at a rate of 118.4 tons/day, is representative of what could be done on a permanent basis operating with 3 skidders. Since the capacity of the chipper was utilized less than 50% of the time, production could be further increased by adding additional skidders. The limitation on production, at present, is the capacity of the boilers to burn the additional fuel, without serious air pollution problems. This limitation is at about 86 tons per Mill day (7 day week) or 120 tons per woods day (5 day week). To utilize the full potential of the chipping system, at least two additional skidders could be added and production increased to 197 T/D.

Increasing production to 197 T/D significantly reduces the cost of biomass. However, to take advantage of this increased production may require a new wood burning boiler.

The uptime on equipment was particularly good and low production for nine weeks of the trial was related to the five week start-up procedure and the loss of one third of trucking facilities for a four week period. Loss of production for equipment failures was negligible.

At present, the existing boilers cannot burn the increased production from the chipper without unacceptable air pollution. Therefore, in the case of the Corner Brook Mill, these savings cannot be realized unless a new boiler is installed or modifications to existing boilers allow increased burning of this fuel.

10.1.2 - *Production - Site 2*

This trial was the first under winter conditions and as noted earlier a winter operation can only be carried out in pure hardwood stands. The trial lasted from January 4th, 1982 to March 19th, 1982. The winter of 1982 was one of the severest on record and adversely affected both fuelwood and pulpwood productions.

The equipment used was similar to the summer operation with the three skidders supplying the chipper. An additional piece of equipment required for winter conditions is a tractor to keep skidder roads clear and to remove snow from the chipper landing. Again chip transport was not always available and production suffered as a result. Other interferences to production were stormy weather and one day when operations were shut completely. During the period, the system operated for 49 days and produced 3721 green tons of hardwood chips.

TABLE 14 - *Production - Site 2*

Date	*Green Tons*	*Remarks*
1982		
Jan 4 - 9	218.2	Trucks towed on side roads - poor conditions. Start-up.
Jan 11 - 16	421.5	
Jan 18 - 23	237.0	Deep snow. Only 2 trucks. Tractor only for one day. Operated only 4 days.

TABLE 14 Cont'd

Date	*Green Tons*	*Remarks*
1982		
Jan 25 - 29	487.1	Tractor two days.
Feb 1 - 5	414.7	
Feb 7 - 13	340.3	
Feb 15 - 19	419.0	
Feb 22 - 26	311.5	Two trucks.
Mar 1 - 5	327.7	Chipper down one day.
Mar 8 - 12	132.4	Chipping only to clean up for shutdown.
Mar 15 - 19	3721.4	

Cords per skidder day - 13.4
Operating days - 49
Tons/Day - 75.9
Best five weeks - 86.1 tons/day

Production at this site was hampered by severe winter weather, deep snow, a tractor being available only part time and not sufficient trucking facilities. However, enough information was gained under winter conditions to conclude that winter harvesting of forest biomass is a viable operation in pure hardwood stands.

10.1.3 - *Production - Site 3*

This was a summer/fall operation using the same equipment as for sites 1 & 2. Site 3 was in the same general area as Site 1. The harvesting method was also similar to Site 1 and consisted of removing residuals (mostly hardwoods) left after pulpwood harvesting. The operation got off to a slow start due to lack of trucking facilities and this deficiency was to hamper production at Site 3 for most of the period. Mill shuts required the operation to close down for three weeks in August. This and the uncertainty of future mill shuts made it impossible to make the necessary commitments to truckers to finance the necessary equipment. The very nature of the operation which was designated "trials" made it difficult to commit to adequate trucking facilities. This was partly offset by trying to integrate trucking of pulpwood and chips as the same motive equipment was used for both operations. However, in most cases the chip operation came second to the pulpwood operation and hence production suffered. As production decreases, costs increase and this is mainly the reason for the increased costs when comparing Site 1 and Site 3. Confidence in the method of harvesting was not affected and there were no experiences at Site 3 to change the conclusions reached at Site 1 that costs could significantly be reduced for an ongoing operation by increasing production with additional skidders and trucks. Because of limitations at the mill in burning solid fuel, the real productive capacity of the system could not be tested. However, as later shown at Site 4, chipper capacity is much above what these trials have been able to achieve and increased production and cost reduction is possible.

TABLE 15 - *Production - Site 3*

Date	*Green Tons*	*Remarks*
1982		
June 14 - 19	318.3	Short of trucks.
June 21 - 25	376.0	Short of trucks.
June 29 - July 2	256.3	4 operating days - short of trucks.
July 4 - 9	494.9	
July 12 - 16	493.7	
July 19 - 23	490.0	
July 26 - 30	400.0	Weather poor.
July 20 - Aug 22	0.0	System shut - Mill not operating.
Aug 23 - 27	406.3	Weather poor.
Aug 30 - Sept 3	562.2	
Sept 7 - 10	354.0	4 operating days.
Sept 13 - 17	408.5	Short of trucks.
Sept 20 - 24	371.0	Short of trucks.
Sept 27 - Oct 1	472.8	Short of trucks
Oct 4 - 8	445.0	Reduced skidders from 3 to 2
Oct 11 - 15	326.3	Reduced skidders from 3 to 2 and worked 3½ days.
Total	6175.3	

In this trial, the lack of trucking facilities adversely affected skidder production as two skidders during the last two weeks of the trial produced almost as much as the three skidders previously. In the trial at Site 1, trucking also adversely affected production rates but to a lesser extent. The true productive capacity of both skidders and the chipper was not fully utilized in these trials and holds the potential for further cost reductions.

10.1.4 - *Production - Site 4*

This was a winter operation in a pure hardwood stand. It was one of the most successful operating periods during the two years of trials. Unfortunately, because of mill shuts, the operating period was brief, but it did show some of the potential of the system. During this period the system operated with five skidders instead of two or three as previously. As noted earlier the production from the system is dictated by the ability of the mill to consume the fuelwood provided. For this brief period, it was possible to increase production by taking advantage of the storage facilities at the mill. Using five skidders, production was in the 165 - 175 ton per day range. At these production rates, the chipper was utilized only 60% of the time and the logistics of tree delivery to the chipper ran smoothly. The chipper is capable of handling additional skidders and increased production.

It is the general opinion that at least two more skidders (7 total) could be added to the system without interference to the productivity of individual skidders. At existing rates, this would give productions in the range of 250 tons/day. The chipper is the most productive unit in the system and with a continuous supply of wood and adequate transportation facilities, production from this unit is in excess of the 250 ton/day noted above. Unfortunately, because of the restrictions due to the ability to consume fuelwood, the full potential of the system has not been tested. However, the experience to date has provided the necessary confidence in the system to project production rates well in excess of those attained. Without existing restraints, production can be increased and costs reduced.

The winter of 1983 was ideal for both pulpwood and fuelwood production due to minimum snowfalls and fine weather. This contrasted to experience during the winter of 1982 when production was curtailed by approximately 25% due to record snowfalls and severe weather conditions. Both operations were in pure hardwood stands as it would be impactical to carry out a winter fuelwood operation in cutover stands as is the summer practice. The only additional equipment needed for winter operation is the services of a tractor for snow clearing.

As in all the trials, production was restricted somewhat by trucking facilities. To get maximum production it is necessary to have trucks waiting for the skidders and not vice-versa. Use of larger trucks would improve this aspect but the proper balance of skidders and trucks is an important consideration for maximizing the economics of the total system.

TABLE 15A - *Production - Site 4*

Date	*Green Tons*	*Remarks*
Jan 20 & 21/83	288.5	2 operating days - 4 skidders
Jan 24 - 28/83	802.8	5 skidders.
Jan 31 - Feb 4/83	856.5	5 skidders.
Feb 7 - 11/83	709.9	4.2 operating days - 5 skidders
Feb 14 - 18/83	181.4	2 operating days - 2 skidders
Total	2839.1	

Avg. tons/day with 5 skidders operating - 166.8

10.2 - *PRODUCTION - PHASE II - SYSTEM II*

10-2-1 - *Production - Site 5*

Operation at this site was for an integrated pulpwood-fuelwood system and is designated as phase 2 of the trials. The initial trial was to evaluate the production potential of the chipper. The limbs and tops left as residue from the pulpwood operation have relatively low bulk densities and therefore present special problems with respect to chipper production.

At this stage, no attempt was made to integrate the chipper into the larger system which consisted of the Koehring Feller Forwarder and the Hahn processor. The aim was to develop a method of efficiently picking up these residues and feeding them into the chipper to achieve production rates which could make the system viable. Even under ideal conditions, production was low. A number of modifications were made to the system to try and improve production rates but without appreciable improvement. The average production for the sixty working days of the trial was only 11.6 tons/day. The maximum production achieved for the chipper was a rate of seven tons per hour. This compares with a maximum rate of 89 tons/hr. for the phase I chipper operation. This does not reflect the relative merits of the two chippers but accentuates the difference in the material being chipped.

Assuming that the chipper could be made more mobile and a more efficient transport system devised, it appears that the system would still be hard pressed to deliver 25-30 tons of biomass per eight hour day. Production would need to be in this range to keep up with the other components in the system. This assumes normal operation of one shift for the chipper and two shifts for the Hahn processor and Koehring Feller Forwarder.

To obtain more detailed information on the capacities of the three main basic pieces of equipment in the system, a trial block was harvested and processed for pulpwood and chips. Details of each phase of this operation were recorded and the results are presented in Table 9. The results confirmed previous experience that the Koehring Feller forwarder could harvest and deliver to roadside more trees than the Hahn could process. The Koehring delivered 32 cords per shift to roadside while the Hahn processed into pulpwood 23 cords per shift. This imbalance must be corrected and experience with the Hahn in other parts of our pulpwood operation suggests the Hahn should be able to overcome this deficit. During this trial there was no evidence to suggest that pulpwood production from the Hahn was adversely affected by having to recover residue for fuelwood. However, it should be noted that the hardwood component of the trial block was quite low and higher percentages of hardwood could adversely affect pulpwood recovery of both the Koehring and the Hahn.

On a per shift basis, the chipper could keep ahead of the Hahn and come close to keeping ahead of the Koehring. See Table 9 . However, since it is only practical to operate the chipper one shift while the other equipment operates two shifts, the chipper must double its production per shift if it is to be integrated into the total system. If some of the problems addressed under Section 8.2.3 can be solved, it should be possible to achieve this goal. However, our experience over a fairly lengthy period fell far short of the required chipper production rate necessary to completely integrate the system.

For the trial blocks A & B, a total of 378.4 tons of fuelwood was recovered. It is estimated that approximately 13% fuelwood material was either left on the site or left at roadside. This does not include stumps. The recoverable biomass represents approximately 17% of the total fibre (pulpwood and fuelwood) on the original site. This appears to be low at 11 tons/acre when compared with biomass recovered from other sites. However, the sites are in no way comparable since two sites had large hardwood components and two sites were pure hardwood sites. One reason for the low biomass per acre can be attributed to loss of foilage as a result of budworm attack. Offsetting this, however, was a high proportion of roundwood from breakage and small diameter wood. Breakage was high due to the brittle nature of the wood as a result of budworm attack and to the method of harvesting. The Koehring can cause damage to small diameter wood due to size of the cutting head and the accumulating features of this unit. As a result of the above, it is difficult to assess whether this amount of biomass is representative of a large part of Bowater forest acreage. There appears to be significant variations as Site 1, which did not recover any limbs or tops from softwood, produced 21 tons/acre. Although it is difficult to make precise projections of available biomass, an average of the two sites indicates a potential of 320,000 tons of biomass as fuelwood for an annual pulpwood cut of 20,000 acres. Again, it must be stressed that this represents potential biomass and not biomass that can be economically recovered.

The nature of the material chipped (limbs and tops) proved to be lower in bulk density when compared with hardwood chips from Sites 1 to 4. The result was a significant reduction in the tons per container and this impacted adversely on transportation costs. It was expected that the lower tons per load would be partly offset by lower moisture which would compensate in part when compared on a fuel value basis. However, on the basis of limited testing, the biomass was only marginally lower in moisture.

One of the adverse features of the fuelwood from Site 5 was its variable nature in both weight and moisture content. This makes it difficult to assign fuel values to the material without costly testing of each load delivered. Material from Sites 1 to 4 were surprisingly uniform in this respect both from summer and winter operations.

TABLE 16

Date	Green Tons	Productive* Hours	Non Productive* Hours	Total* Hours	Remarks
July 27					Arrived at site
July 28-30	26.7	8	16	24	Start training
Aug 2-6					Mill shutdown
Aug 9-13					Mill shutdown
Aug 16-20					Mill shutdown
Aug 23-27	26.7	16	24	40	
Aug 30-Sept 3	42.6	19	21	40	
Sept 6-10	42.6	16	16	32	Labour Day
Sept 13-17	16.0	8	32	40	3 days-waiting on parts
Sept 20-24	32.0	18	22	40	1 day-waiting on parts
Sept 27-Oct 1	58.6	24	16	40	1 day-waiting on parts
Oct 1					Travel to Brakes Cove
Oct 4-12		0	56	56	Alterations
		START INTEGRATED TRIAL			
Oct 13-15	48.0	16	8	24	1 day-Electrical
Oct 18-22	80.0	26	14	40	
Oct 25-29	69.3	23	17	40	
Nov 1-5	74.5	28	12	40	
Nov 8-12	53.3	23	17	40	1 day-Mech.Down
Nov 15-19	53.3	25	15	40	
		FINISH INTEGRATED TRIAL			
Nov 22-26	74.6	29	11	40	Shutdown
Sub-Total (Trial)	378.4	141	83	224	28 days worked
Sub-Total (Other)	319.8	138	214	352	32 days worked
Grand Total	698.2	279	297	576	60 days worked

131 Boxes Produced for 60 working days = 2.18 boxes/day

4 Boxes/Day - Highest Production level reached

* Taken from Daily Operator's Reports

Table 17

Date	Kgs Gross Weight	Kgs Truck & Box	Kgs Chips	Tons
Sept 27	17,000	13,400	4,400	4.85
Sept 28	17,800	13,400	4,400	4.85
Sept 29	18,000	13,400	4,600	5.07
Sept 30	16,700	13,340	3,360	3.70
Oct 14	18,100	13,400	4,700	5.18
Oct 18	17,400	13,340	4,060	4.48
Oct 19	17,600	13,400	4,200	4.63
Oct 19	17,700	13,400	4,300	4.74
Oct 20	19,300	13,400	5,900	6.50
Oct 21	19,100	13,400	5,700	6.28
Oct 21	17,300	13,340	3,960	4.37
Oct 21	20,200	13,400	6,800	7.50
Oct 22	20,200	13,400	6,800	7.50
Oct 22	18,900	13,400	5,500	6.06
Nov 17	18,600	13,400	5,200	5.73
Nov 23	17,100	13,400	3,700	4.08
			Total Weight	85.30
			Total Weighed	16
			Averge	5.33

Total Production

5.33 tons x 131 loads = 698.2 tons

Our experiments indicate that best results from the system are possible when the chipper follows the Koehring and Hahn as closely as possible. Delays in processing the residue cause problems such as increased grit content from dust and other factors.

10.3 - *COST OF BIOMASS - PHASE I - SYSTEM I*

Detailed costs are available for all phases of the trial and are obtained from the regular woods' costing system. A typical cost statement showing monthly and year to date information is shown in Table 18. A more detailed breakdown of each item can also be extracted from the records. For example, item "923 - processing", would show this item is made up of chipper rental, chipper repairs, chipper operator labour, etc. The cost system can supply the dollar costs on each item including major equipment so that more detailed cost analysis can be made.

The costs reported for Sites 1 to 5 are actual costs incurred during the months of the trials and in most cases are not necessarily indicative of an ongoing operation because of the high cost of equipment rentals. Depreciation costs are also not typical. A better analysis of costs for an ongoing operation is contained in Section 10.5.

10.3.1 - *Cost of Biomass - Site 1*

Detailed costs at Site 1 are given in Tables 20, 21, 22, 23 and 24. A breakdown of costs for skidding (cost to roadside), chipping, transportation and overhead are shown. These costs include all costs associated with the trial over a three and one half month period and include start-up costs and rental costs. A total of $343,102.00 was expended to produce 8992 green tons of biomass for a cost per ton of $38.17.

While these costs provide useful information they are not representative of costs for an ongoing operation. Costs for the trial are on a rental basis for the chipper instead of a depreciated basis and do not represent the reduced cost possible by increasing production from the system. Production during the trial was mainly controlled by the number of skidders in operation. Increased production is possible by increasing the number of skidders as the chipper has excess capacity. As

ABLE 18

OWATERS NEWFOUNDLAND LIMITED - WOODS DEPARTMENT
EPARTMENTAL STATEMENT - OCTOBER 1981 PERIOD 10 PAGE NO. 28A

	----CURRENT	MONTH----	-----Y E A R	T O D A T E	------
>CAN. DOLLARS<	ACTUAL	BUDGET	ACTUAL	BUDGET	PRIOR YR
BIO MASS PROJECT		8200			
02-OPERATING LABOUR			5,636		
92-TRUCK OPERATORS	583		1,643		
16-FOREMAN/SUB-FOREMAN	1,883		11,646		
11-PURCHASED SERVICES			243		
00-LUBRICANTS	476		1,749		
31-GASOLINE			227		
33-STOVE,FURN OIL,KERO			54		
08-RIGGING	596		4,655		
11-COOKHOUSE EQUIPMENT			29		
13-DIESEL FUEL	2,596		6,868		
15-MISC SUPPLIES	4		8,094		44
18-CLASS 2 MATERIALS			28		
20-EXPENDABLE TOOLS			371		
30-POWER SAW PURCHASES	134		134		
32-BARS CHAINS FILES	189		724		
34-POWER SAW PARTS	98		337		
32-TRAVEL			102		
13-LICENSE FEES	1,172		2,002		
52-BAL-TRANS-CONTRS-YRLY					13,061
84-MOVING EQUIPMENT			451		
115-VEHICLE RENTAL	1,011		3,444		
121-REPAIR MATERIALS	72		4,883		
31-SKIDDING	20,189		66,856		
38-BUSING	587		1,508		
123-PROCESSING	45,430		98,278		
31-UTILITY VEHICLES	751		2,058		
32-COOKHOUSE EXPENSE	2,718		7,763		
150-EQUIPMENT REVENUE			2,250		
152-CAMP MEALS			231		
81-DEPRECIATION	391		1,564		
86-CONTRACT TRUCKING	19,500		60,675		
* * T O T A L * *	98,380		294,503		13,105

noted, this potential could not be realized because of fuel burning restrictions at the mill.

The data in Table 19 which follows gives more useful data as it projects cost which could be possible for an ongoing operation. A more detailed cost analysis in 1983 dollars is contained in Section 10.5.

TABLE 19

1) Actual cost for 3½ month trial period

Skidding	$10.06	green ton
Chipping	14.36	" "
Chip Transportation	8.43	" "
Overhead	5.32	" "
	$38.17	

2) Actual cost for best ten weeks (all equipment operating).

Skidding	$ 8.43
Chipping	10.80
Transportation	8.43
Overhead	4.30
	$31.96

3) Actual cost for best four weeks.

Skidding	$ 7.76
Chipping	9.95
Transportation	8.43
Overhead	3.96
	$30.09

4) Projected cost for best ten weeks - chipper costs on a depreciated rather than a rental basis.

Skidding	$ 8.43
Chipping	6.72
Transportation	8.43
Overhead	4.30
	$27.88

5) Projected cost if system expanded to utilize full chipper capacity (5 skidders instead of 3) and using depreciated costs for chipper.

Skidding	$ 8.43
Chipping	4.42
Transportation	8.43
Overhead	3.50
	$24.78

The above data indicates it is possible to reduce the cost of biomass significantly from the overall trial cost of $38.17 per ton. On an ongoing basis and for production capacity in the range of 110 - 120 tons/day, cost would be in the range of $28.00 - $30.00 per ton. To further reduce costs to $25.00 per ton requires more fully utilizing chipper capacity and increasing production to the 190-200 ton/day level. These costs are for Site 1 only and represent specific conditions as to weather, terrain and hardwood component. Costs are in 1981 dollars. Costs in Section 10.4 are in 1983 dollars.

10.3.2 - *Cost of Biomass - Site 2*

The high cost at Site 2 is attributed to a severe winter and the short number of operating days. Included in the cost is depreciation, rental and other field costs for the months of January, February and March. Actual operating days were 49 or 9.8 weeks.

An extra cost during winter operation is the requirement for a tractor which adds approximately $3.00 per ton to costs. Again, an imbalance between trucking and skidding reduced production and increased costs.

Chipper rental costs alone were $16.11 per ton against an eight year straight line depreciated cost of $2.50 per ton.

The total cost for the three months was $190,474.00. Production for the winter operation was 3721 tons for a cost per ton of $51.19

10.3.3 - *Cost of Biomass - Site 3*

Cost of biomass at Site 3 was higher than Site 1. This was the result of a number of factors, chief among which were increased labour costs per hour, increased fuel costs, lower production and a shutdown during August when the mill was not operating. Problems with trucking are identified under 10.1.3 and are the main reason for reduced production. Total cost for the 70.5 day operating period was $278,490.00. During this period, 6175.1 tons of hardwood chips were produced for a cost of $45.10 per ton. Apart from the increased cost of labour and material, there was nothing to suggest that conclusions reached during the earlier trials at Site 1 were significantly changed.

10.3.4 - *Cost of Biomass - Site 4*

This Site operated with five skidders versus the three skidders of previous trials. Although production was highest, costs were not as low as predicted. This is partly due to the short period of the trial - 19 days. It was necessary to shut down because storage at the mill could not accommodate the increased production. For more realistic costs on an ongoing basis the projected cost figures in Section 10.5 are a better guide.

A total of 2839 tons of biomass were produced for a cost of $115,113.00 or $40.55 per ton.

10.3.5 - *Cost of Biomass - Site 5*

It is almost impossible to come up with any relevant cost data for Site 5 trials. The trials were extremely costly due to the low production and the cost of setting up the chipper on a mobile rig with loader, etc., as shown in Figure . In the middle of the trials, it was necessary to make further modifications. Rental costs for the chipper were high at $15,540.00 per month and the manufacturer would not provide the equipment for a shorter than a six month rental period. As it turned out the chipper was in production for only three months.

The original concept was for fuelwood to take a part of the cost of delivery of residue material to roadside. However, even when considering this material a waste product at roadside, the cost of the material is in excess of $100.00 per ton (Section 10.4). Our costs which include higher rental costs and expensive start-up and modification costs were well in excess of the above.

Production would have to be in the range of 40-50 tons per day and the material considered a waste at roadside to compete with other forms of fuelwood.

TABLE 20: SUMMARY OF OPERATING COSTS ON BOWATER-ENFOR TRIAL

Item	COST ($)			% of Total Operating Cost
	Total	Per Day	Per Ton	
Skidding	90289.01	940.51	10.06	26.3
Chipping	129122.99	1345.02	14.36	37.7
Chip Transportation	75862.00	790.23	8.43	22.1
Overhead	47828.00	498.21	5.32	13.9
TOTAL	343102.00	3573.97	38.17	100.0

TABLE 21: BREAKDOWN OF SKIDDING COSTS ON BOWATER-ENFOR TRIAL

Item	COST ($)			% of Total Operating Cost
	Total	Per Day	Per Ton	
Operators' Wages	19386.00	201.94	2.16	5.6
Fellers' Wages	18834.00	196.19	2.10	5.5
Bonus	13728.00	143.00	1.53	4.0
Fuel	4661.34	48.56	0.52	1.4
Lubricants	852.67	8.88	0.10	0.2
Repairs	1533.00	15.97	0.17	0.4
Rigging	3967.00	41.32	0.44	1.2
Power Saws	2697.00	28.09	0.30	0.8
Depreciation	24630.00	256.56	2.74	7.2
TOTAL	90289.01	940.51	10.06	26.3

TABLE 22: BREAKDOWN OF CHIPPING COSTS ON BOWATER-ENFOR TRIAL

	COST ($)			
Item	Total	Per Day	Per Ton	% of Total Operating Cost
Operators Wages	8081.00	84.18	0.90	2.4
Buckers Wages	5619.00	58.53	0.62	1.6
Bonus	4387.00	45.70	0.49	1.3
Fuel	5066.66	52.78	0.56	1.5
Lubricants	426.33	4.44	0.05	0.1
Repairs	4744.00	49.42	0.53	1.4
Power Saws	899.00	9.36	0.10	0.3
Rental	99900.00	1040.62	11.11	29.1
TOTAL	129122.99	1345.02	14.36	37.7

TABLE 23: BREAKDOWN OF CHIP TRANSPORTATION COSTS ON BOWATER-ENFOR TRIAL

Item	COST ($)			% of Total Operating Cost
	Total	Per Day	Per Ton	
Contract Trucking	69450.00	723.44	7.72	20.2
Operators' Wages	1922.00	20.02	0.21	0.6
Miscellaneous	4490.00	46.77	0.50	1.3
TOTAL	75862.00	790.23	8.43	22.1

TABLE 24: BREAKDOWN OF OVERHEAD COSTS ON BOWATER-ENFOR TRIAL

Item	COST ($)			% of Total Operating Cost
	Total	Per Day	Per Ton	
Foreman's Wages	8474.00	88.27	0.94	2.5
Busing	5945.00	61.93	0.66	1.7
Camp Expenses	9454.00	98.48	1.05	2.8
Utility Vehicles	2927.00	30.49	0.33	0.8
Licence Fees	2093.00	21.80	0.23	0.6
Moving Equipment	2303.00	23.99	0.26	0.7
Miscellaneous	16632.00	173.25	1.85	4.8
TOTAL	47828.00	498.21	5.32	13.9

10.4 - *ANALYSIS OF COST AND PROJECTED COST*

The very nature of trials makes it difficult to assign realistic costs due to start-up and other factors. There is also the temptation to be optimistic. Production rates for the best periods are sometimes selected as normal and charges for overhead and depreciation are not always representative of the true costs represented by these factors. This becomes particularly important in forestry as it is usually a seasonal activity.

The trials at Bowater were carried out over a two year period, and expenses were incurred in 1981, 1982 and 1983. The trials started in July, 1981, and were completed in March, 1983. This makes it difficult to make cost comparisons between sites because of high inflation during the period.

To present a complete picture on expenditures, the following states costs in three different forms: (I) actual costs as incurred during the period of the trials, (II) total costs to Bowater for the complete period July, 1981, to March, 1983, and (III) projected costs in 1983 dollars based on straight line depreciation instead of rentals. Projected costs, item (III), are the most realistic for an ongoing operation. It should also be noted that Site 1 expenses did not include fringe benefits but they are included for all other sites.

Item (I) Actual Costs - Trial Period

Site 1 - System I

July 1981 - November 1981
Total Cost - $343,102.00
Total Tons - 8992
Cost/ton - $38.17

Site 2 - System I

January 1982 - March 1982
Total cost - $190,474.00
Total Tons - 3721
Cost/ton - $51.19

Site 3 - System I

June 1982 - October 1982
Total cost - $278,490.00
Total Tons - 6175
Cost/ton - $45.10

Site 4 - System I

January 1983 - February 1983
Total cost - $115,113.00
Total Tons - 2839
Cost/ton - $40.55

Site 5 - System II

August 1982 - November 1982
*Total cost - $101,063.00
Total Tons - 698
Cost/ton - $144.78

*This is a rough estimate of actual costs during this period.

The above costs include rental costs for the chipper and depreciated costs (30% declining balance) for skidders for the months while trials were in progress. Although depreciated costs are not included for the full year, the amount written off is at least equivalent to a year's depreciation on an eight year straight line depreciated basis. The high rental chipper costs in particular make the above costs higher than what can be expected for an ongoing operation.

Item (II) Actual Yearly Cost to Bowater for the Trial Period - July 1981 - March 1983.

1981 - System I

Total cost - $345,610.00
Total Tons - 8992
Cost/ton - $38.43

1982 - System I

Total cost - $602,616.00
Total Tons - 9896
Cost/ton - $60.89

1983 - System I

Total cost - $129,739.00 (end of April 1983)
Total Tons - 2839
Cost/ton - $45.70

1981 - 1983 - System I

Total cost - $1,077,965.00
Total Tons - 21,727
Cost/ton - $49.61

Actual costs for System II are excluded as they include costs associated with pulpwood production and are so high on a per ton basis as to be meaningless. Projected costs for System II as contained in Table 26 are more relevant.

The above costs are total costs incurred and they do not reflect the contribution made by ENFOR towards these trials. Note the higher costs in 1982 reflect that chipper costs of $19,980 per month are included for the full twelve months even though the chipper operated for only 117.5 operating days in 1982. The total cost of chipper rental in 1982 was $239,760 or a cost per ton of $24.23. This compares with total chipper costs of $5.50 to $6.00 a ton on an ongoing basis. This must be kept in mind when reviewing the above costs.

The above are negative factors contributing to the high cost of the trials. On the positive side, since the chipper rental costs were on the basis of a rental purchase agreement, Bowater now owns outright the Morbark chipper which has been completely paid for over the two year period. The chipper has been depreciated and is in excellent condition and this will be reflected in lower costs for chips harvested in the summer of 1983 and beyond. Since the three skidders were new at the start of the trials and have been depreciated on a 30% declining balance basis, we also have three skidders in good condition which have been depreciated by 50% in two years. This will also reflect lower costs for sometime in the future. These factors are important to consider when evaluating the true cost of harvesting fuelwood. Costs as projected under item three are, therefore, the best guide to the actual costs of a fuelwood operation.

Item (III) Projected Cost - Ongoing Operation

The following are projected costs (1983 dollars) (Table 25) for an ongoing fuelwood operation based on a Phase I - System I concept. Costs are shown for 150 ton per day and a 200 ton per day production rate. These are the minimum and maximum production rates for a five skidder operation.

TABLE 25 PROJECTED COST - SYSTEM 1

Skidding Cost

			Production & Daily Cost	
			@150 T/D	@200 T/D
1.	5 skidder operators	$141.56/day	$707.80	$707.80
2.	5 cutters	$138.75/day	693.75	693.75
3.	Fuel	@$0.65/ton	97.50	130.00
4.	Repairs	@$2.00/ton	300.00	400.00
5.	Rigging	@$0.45/ton	67.50	90.00
6.	Power saws	@$0.45/ton	67.50	90.00
7.	Depreciation (5 skidders)	$276.25/day	$ 276.25	$ 276.25
8.	Sub-Total		$2210.30	$2387.80
9.	Skidder cost/ton		14.73	11.93

Chipping Cost

1.	Chipper operator	@$145.32/day	$ 145.32	$ 145.32
2.	Utility operator	@$138.75/day	138.75	138.75
3.	Fuel	@ $0.65/ton	97.50	130.00
4.	Repairs	@ $1.75/ton	262.50	350.00
5.	Miscellaneous	@ $0.50/ton	75.00	100.00
6.	Depreciation	@$196.67/day	196.67	196.67
7.	Sub-total		$ 915.74	$1060.74
8.	Chipper cost/ton		6.10	5.30

Transportation

1.	Sub-total		$1500.00	$2000.00
2.	Cost/ton		10.00	10.00

Overhead

1.	Foreman	@$30,000/yr.	$ 200.00	$ 200.00
2.	Busing	@$100.00/day	100.00	100.00
3.	Camp expenses	@$191.70/day	191.70	191.70
4.	Miscellaneous & other overhead		200.00	200.00
5.	Sub-total		$ 691.70	$ 691.70
6.	Overhead cost/ton		4.61	3.46

	TOTAL COST/DAY		$5317.74	$6140.24
	Total cost/ton		$ 35.45	$ 30.70

TABLE 26 PROJECTED COST - SYSTEM II

Chipping rig

Operators' wages	-	$145.32
Fuel	-	75.00
Repairs	-	200.00
Misc.	-	50.00
Depreciation	-	145.00
Sub-total		$615.32
Foreman	-	$200.00
Tractor	-	150.00
Utility	-	75.00
Miscellaneous	-	100.00
Sub-total		$675.00
Trucking	-	$183.12
Total	-	$1323.44

Tons - 11.62 tons/day

Cost/ton $113.89

Note the following with respect to projected costs.

1. Hourly labour costs include fringe benefits and bonus.
2. Depreciation is based on straight line depreciation and costs as contained in Table 27.
3. Repair costs are based on the assumptions in Table 27 and are the average for the first eight years.
4. Hourly labour costs are about 37% of total cost.
5. Operating under winter conditions, $450.00/day should be added to projected costs to cover hire of a tractor for snow clearing.

TABLE 27

BIOMASS HARVESTING EQUIPMENT
PURCHASE PRICE & ASSUMPTIONS FOR DEPRECIATION & MAINTENANCE

3 Timberjack Model 450 skidders @ $66,300 each

Estimated life for depreciation - 8 years
Estimated maintenance cost:
0 - 4 years 10% of cost per year
4 - 8 years 20% of cost per year
8 years - 25% of cost per year
(1 shift operation, for an operating unit of 10 skidders)

1 Morbark Model 22 RXL Chiparvestor @ $295,000

Estimated life for depreciation - 10 years
Estimated maintenance cost:
0 - 4 years 10% of cost per year
4 - 8 years 15% of cost per year
8 years - 25% of cost per year
(1 shift operation)

1 Hahn Shortwood Harvester @ $137,000

Estimated life for depreciation - 8 years
Estimated maintenance cost:
0 - 4 years 20% of cost per year
4 - 8 years 30% of cost per year
8 years - 40% of cost per year
(2 shift operation)

1 Koehring Feller Forwarder, Model K3FF @ $550,542

Estimated life for depreciation - 8 years
Estimated maintenance cost:
0 - 4 years 20% of cost per year
4 - 8 years 30% of cost per year
8 years - 35% of cost per year
(2 shift operation)

1 Bruks Model 1000 drum chipper @ $174,000

Estimated life for depreciation - 8 years
Estimated maintenance cost:
0 - 4 years 15% of cost per year
4 - 8 years 20% of cost per year
8 years - 25% of cost per year
(1 shift operation)

N.B. All maintenance cost estimates include routine servicing.

10.5 - *BIOMASS CONVERSION*

10.5.1 - *Combustion*

As part of the trial, the contract with Supply and Services calls for burning tests to be carried out to provide the basis for estimating the oil equivalent value of the chips. This was necessary to assess the economics of the operation.

A series of biomass burning trials were initiated but because of the errors inherent in the measurement of the biomass, the results were erratic. A better assessment of the economics of biomass was based on the longer term reduction in oil over a three month period when burning hardwood chips. The conclusions reached concerning the oil equivalent value of a ton of green chips has held up over the two year period of trials.

It is not possible to conduct a trial of 100 tons of hardwood chips separately from bark while the mill is operating. This would require a complete shut of the Wood Preparing operation for up to 16 hours which is not possible without losing paper production. The alternative is to dump bark from the wet barking operation into the receiving waters which is environmentally unacceptable. Therefore, a burning trial on hardwood chips was planned and conducted during the Labour Day shutdown of the Mill.

To carry out the trial without wasting the steam produced, the trial was scheduled for the 12-8 shift prior to start-up of the paper machines at 8 a.m. This shift has a minimum requirement for steam but demand is erratic. Again, because of these restrictions, the timing was difficult and steam flows variable. The trial lasted about five hours and about 60 tons of hardwood chips were burnt.

TABLE 28

	Sept. 9/81
Pounds of green chips fired	124,100
Pounds of O.D. chips fired	69,230
Average Moisture	44.2%
Steam meter reading - start	4858
Steam meter reading - finish	5217
Test Duration	4 hrs. 50 mins.
Steam Integrator Factor 1000	
lbs. Steam Generated From Chips	371,583

10.5.1 Cont'd.

Bbl/oil equivalent (1 bbl. = 5300 lbs steam)	70.1
Tons of green chips burnt	62.05
Bbl/oil per green ton chips	1.13
Heating value of chips Btu/lb bone dry	8700
Heat value of chips as fired	4855
Boiler effieincy	59.8%
Price of oil/bbl. (Sept./81)	$24.25
Equivalent fuel value of chips(1981 Dollars)	$27.40

Although the above trial was carried out under adverse conditions and measurements are not as accurate as one would like, the result indicating a ton of green chips is equivalent to 1.13 bbl/oil is very close to values reported in the literature. Another trial conducted in 1982 on chips only confirmed a value of about 1.1 bbl/oil equivalent for one green ton of biomass when the boilers were fired on chips only. As noted earlier, the cost of biomass in western Newfoundland even under the best operating conditions is too high at a 1.13 bbl/oil equivalent oil prices. However, the following data will indicate a higher bbl/oil equivalent can be used when mixing chips with wet bark under the conditions existing at Bowater Newfoundland Limited. The following sections under steam generation and oil equivalents will support this thesis.

10.5.2 - *Steam Generation and Oil Equivalent*

To put in perspective the effect of forest biomass on steam energy requirements, it is useful to look at some historical data on energy for steam production. Appendix 2 has a Table indicating the sources of energy for steam production for the period 1970 - 1982. Steam energy is produced mainly from Bunker "C" (No. 6) oil with small amounts from electricity and bark. Energy from electricity and bark is shown as equivalent barrels of oil.

Energy per ton of product has gone down over the period as a result of increased production and savings initiated in response to higher energy prices.

For the period 1970 - 1978, the average steam energy from bark was equivalent to 37,833 bbl/oil per year or 6.0% of total steam energy.

10.5.2 Cont'd.

For the period 1979 - 1980, the average steam energy from bark was equivalent to 68,905 bbl/oil per year or 11.4% of total steam energy. This reflects the installation of new bark recovery facilities at the Mill in 1979.

In 1981, the average steam energy from bark and forest biomass was equivalent to 89,143 bbls of oil per year or 14.3% of total steam energy. This increase reflects the additional energy from hardwood chips which was used during the months of July, August, September, October and part of November.

1982 was a difficult year with considerable downtime in the Mill. This adversely reflects on energy per ton and it is difficult to make comparisons with 1981. However, forest biomass continued to make a worthwhile contribution to energy needs.

To indicate more clearly the effect of the introduction of forest biomass as a source of steam energy, Table 29 shows a comparison of the first six months of 1981 when no hardwood chips were burnt for a 3½ month period.

TABLE 29

	6 Months Jan-June/81	6 Months July-Dec/81
Production (Newsprint) tons	199,411	204,562
Barrels of oil	268,145	247,038
Barrels of oil/ton	1.34	1.21
Barrels of oil equivalent - bark & forest biomass	36,156	52,987
Barrels of oil equivalent - electric power	14,539	2,896
Total barrels of oil plus oil equivalent	318,840	302,921
Barrels of oil plus equivalent/ton	1.60	1.48
% Steam energy from solid fuel (bark & chips)	11.3%	17.5%

A further comparison of the effects of burning forest biomass (wood chips) is given in Table 30
This compares the months in 1981 when biomass (wood chips) were burnt with the same months in 1980 when no chips were burnt.

10.5.2 Cont'd.

TABLE 30

	1980		1981	
	Tons/News	Bbl/oil	Tons/News	Bbl/oil
July	35,540	41,109	36,212	40,408
Aug.	30,571	37,049	30,654	32,303
Sept.	27,339	36,851	29,510	33,235
Oct.	38,093	46,568	40,425	47,097

TABLE 31

	1980	1981	
	Bbl/Oil/Ton/News	Bbl/Oil/Ton/News	
July	1.16	1.12	
Aug.	1.21	1.05	
Sept.	1.35	1.13	
Oct.	1.22	1.17	(one boiler only on solid fuel for part of month)

The above Tables indicate the beneficial effects of wood chips on reducing the oil requirements to produce a ton of paper.

To more accurately assess the oil equivalent value of a green ton of wood chips when mixed with the wet bark, a more detailed examination of the steam generation from solid fuel is necessary.

In 1980, steam generation from bark averaged 45,406 lbs. steam/hour over the 12 month period. If we compare the months of August and September in 1980 and 1981, it is seen that steam production from solid fuel almost doubled in August and September of 1981 when wood chips were burnt with bark. Steam generation averated 42,476 lbs/hour in August - September, 1980, versus 81,157 lbs/hour in August - September, 1981, or an increase of 38,681 lbs/hour.

At a conversion equivalent to 5300 lbs. steam per bbl/oil, the increase is equal to 7.30 bbl oil/hour. During the August - September period of 1981, 4200 green tons of biomass were burnt or a rate of 3.24 green tons/hour. If we assume all the increase in

10.5.2 Cont'd.

steam in 1981 is due to burning wood chips, then a green ton of biomass is equivalent to 7.30/3.24 or 2.25 bbls of oil. This is over twice the amount one would expect if burning chips only. Since we cannot separately measure quantities of bark and chips in the mixture, it is necessary to estimate the steam generation from bark based on past experience. As noted earlier, actual steam from bark in August - September, 1980, was 42,476 lbs/hour. To be on the safe side we have estimated 51,000 lbs/hour as the steam generated from bark in August - September, 1981. This leaves 30,157 lbs. steam/hour increase (81,157 - 51,000) as a result of mixing 3.24 green tons of chips with the bark. On this basis, a green ton of chips is equivalent to 1.75 bbls of oil.

The reason for the higher oil equivalent (1.75) for a ton of green biomass than is reported in the literature (1.1 - 1.3) arises from the fact that the relatively dry chips lower the moisture content of the total mixture of bark and chips and increases the boiler efficiency. Therefore, the effective energy increase of the total mixture (12.9 T/hour bark + 3.24 T/hour chips) is credited to chips and increases the oil equivalent value. The boiler effieincy when burning bark only is in the range of 40 - 45% and increases to 60 - 65% when burning a mixture of chips and bark. Because of the difficulties of measurement, etc., it is difficult to accurately determine boiler efficiency improvement to get the measured increase in steam generation. The effect has taken place over a long enough period to give confidence to the 1.75 bbl/oil per green ton being used to put a value on the chip biomass.

Using the 1.75 bbl/oil per green ton equivalent, the value of biomass can be stated relative to various oil prices.

TABLE 32

Cost of oil/bbl.	Value of biomass per green ton
$20.00	$35.00
25.00	43.75
30.00	52.50
35.00	61.25

10.5.2 Cont'd.

The above puts in perspective the value of forest biomass as an alternative fuel under the conditions existing at the Corner Brook Mill. Even at present fuel prices of $30.00 per barrel, forest biomass is competitive with oil becuase of the beneficial effect on boiler efficiencies when burning it with wet bark. It is stressed that these economics are for a specific trial period under good harvesting conditions and specific boiler and fuel conditions. If bark moistures are already low in a given mill situation, boiler efficiencies may be only minimally influenced by wood chips and different economics will apply. Without knowing the specific mill conditions, it is safe to assume that forest biomass is at least equal to 1.1 bbls of oil per green ton. For biomass to become a major energy source, as an alternative fuel, the cost of oil energy would have to increase or methods found to more efficiently harvest forest residues. However, many mills may have conditions which make the economics of forest biomass more advantageous than the conventional value assigned to it. This changes the economics from poor to favourable. Each mill has to evaluate their conditions and the economics are greatly influenced by how efficiently present bark is being burnt. Bark moisture and boiler efficiency are two of the major factors in the above.

Our trials indicate a value for biomass higher than was originally assumed and this has encouraged us to continue with the above system for harvesting forest biomass.

11.0 WINTER VS. SUMMER OPERATION

For biomass harvesting to be successful as a year round source of fuel, it is important that harvesting be carried on during the winter months. In a papermaking facility, steam energy needs are continuous over the twenty-four hours of a production day as well as for approximately 358 days of the year. In addition to energy needs, the high cost of equipment used for harvesting of forest residues make it imperative to utilize equipment as many days as possible throughout the year. In this respect, some pulpwood harvesting is now being carried out on a two shift basis. There are certain conditions where fuelwood harvesting might also be possible on a more than one shift basis. The chipper operation in System II has the potential for two shift or three shift production if stockpiles of fuelwood trees can be made available.

In recognizing the necessity for procurement of forest biomass on a year round basis, it was obvious that some changes were required when compared with a summer operation similar to Phase I - System I. In that operation, hardwood residues from a pulpwood cutover area were salvaged for fuelwood. This is not practical during the winter for two main reasons as follows: (1) a large percentage of wood residuals are on the ground and would be covered with snow and (2) the exposed nature of cutover sites require continuous snow clearing because of drifting. In normal pulpwood operations, there is a measure of protection of the harvesting site due to the windbreak effect of a coniferous tree forest. In cutover areas, the site is exposed and is unworkable in the climatic conditions of a Newfoundland winter. Because of this, the winter fuelwood operation was conducted in a full hardwood stand. Although the hardwoods do not provide the protection of a softwood or mixed softwood - hardwood stand, the exposed nature of the site is minimized. In full hardwood stands, the tons of biomass per acre is concentrated which makes operating under winter conditions a lot more practical.

As there are not many pure hardwood stands in areas close to the Mill, there is some concern as to how long these supplies would support a winter operation. However, there may be other sources of winter fuel such as on substandard sites which could provide a continuity of supply. Clearing of substandard sites to improve soil conditions and plant species more compatible to these sites may have potential as a source of fuelwood.

11.0 Cont'd.

If silviculture improvements and fuelwood requirements compliment each other, then the economics for both processes become more favourable.

The cost of harvesting biomass under winter conditions will be increased somewhat over summer conditions. A great deal depends on weather conditions as this affects skidder production. However this is no more severe than for pulpwood harvesting under winter conditions. The increased cost of winter harvesting can be offset by crediting it for clearing of the sites so that species favourable for pulpwood can be planted. There are obvious silviculture benefits in clearing "pure hardwood" sites for replanting to softwoods for pulpwood. For Bowater Newfoundland, where transportation costs are a major part of wood costs, the removal of hardwoods and replacement with softwoods is particularly beneficial on sites close to the Mill.

As a result of experience gaining during two winters of harvesting fuelwood, Bowater Newfoundland is confident that forest biomass harvesting can be successfully implemented on a year round basis.

12.0 CONCLUSIONS

Two years of trials under a variety of conditions have shown that forest biomass harvesting can be carried out successfully. In System I, we believe we have the equipment to procure fuelwood in quantities in excess of 200 tons per day. Depending on the quantities of hardwoods available on a Company's forest holdings, one or more systems could provide a significant portion of the steam energy requirements of a paper mill. However at today's oil prices, the economics are marginal when hardwood chips are burnt at an equivalent fuel value of 1.1 barrels of oil for a green ton of chips. At Bowater Newfoundland where chips mixed with bark improve the overall efficiency of the mixture, the oil equivalent value is higher and under these conditions, we consider the economics to be favourable. It is proposed to continue with burning of hardwood chips.

The experience gained to date in these trials is valuable for assessing the long term energy sources for the Mill. We now have complete confidence in the ability to deliver large quantities of fuelwood on a year round basis. More information is needed in estimating the quantity of fuelwood within a reasonable transportation distance of the Mill. Such an inventory would be necessary before installing new and larger solids burning steam generation facilities.

We wish to thank and acknowledge the assistance of the following:

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F. Pollett
R.C. Dobbs

In addition, the success of the project was mainly due to the commitment and efforts of the Bowater Woodlands group who successfully implemented the techniques of biomass harvesting. Finally our thanks to the Mill Personnel who accommodated, with minimum expenditure, a new fuel source.

We also wish to acknowledge with thanks the assistance by many Woodlands and Mill personnel in the preparation of the final report.

The financial assistance provided under the ENFOR program is also gratefully acknowledged.

APPENDIX 1 & 2

APPENDIX 1

ENFOR PROJECT P-191

INTEGRATED FULL-TREE LOGGING

FIELD PROCEDURES FOR CRUISE AND DISTURBANCE STUDIES

MIXEDWOOD STAND

BLOCK LAYOUT

A. At least four 1 ha blocks will be established in the area to be harvested. Blocks will be located so that they enclose conditions which are representative of the area.

B. Each block will be 100 m square, comprised of a grid of 20 m intervals, for a total of 12 line transects each 100 m long. (See diagram).

C. Each line intersect will be marked with a number metal stake so that they may be located after harvesting. (36 stakes per block)

D. The nine 20 m square plots (0.04 ha each) forming a + in the centre of each block will be measured in detail as outlined below.

COLLECTING FIELD DATA

BEFORE HARVESTING

A. For each 0.04 ha plot (20 m x 20 m)

1. Tally all trees > 5 cm Dbh (at 1.3 m) by species and 2 cm diameter classes. Separate living and sound dead stems. Record Dbh of all sound downed trees separately from standing trees. Record only those trees with butts within the plot boundary. Mark

with a blaze at BH all standing and downed trees not sound enough for skidding. Do not tally these trees.

2. Select 10 trees of each major species (> 25% by basal area) to cover the range of diameters (> 5 cm Dbh) in the plot. Record total height to nearest 0.3 m and Dbh to 0.1 cm of each sample tree.
3. Select a maximum of 5 trees of each minor species (> 25% by basal area) and obtain heights and diameter as above.

B. For each 0.0025 ha plot (5 m x 5 m)

1. Tally all woody vegetation ≤ 5 cm Dbh and > 1.3 m in height as in A. 1 above, by 1 cm Dbh classes.
2. Select 3 stems of each species and obtain heights and diameters as above.

C. For each 0.0004 ha quadrat (Quadrats, 2 m x 2 m, are established in clusters of four around each corner post of the nine main plots - see diagram).

1. Record the number by species of all stems of woody vegetation < 1.3 m in height.

D. For each line transect (12 transects each 100 m long)

1. Record the intercept distance occupied by each of the categories described on the tally card.

AFTER HARVESTING

E. For each 0.04 ha plot

1. Tally any standing trees > 5 cm Dbh as previously.
2. Record Dbh by species of all sound trees > 5 cm Dbh lying on the ground and having their butts within the plot.

F. For each 0.0025 ha plot

1. Tally all standing woody vegetation ≤ 5 cm Dbh as previously.
2. Record Dbh by species of all sound stems ≤ 5 cm Dbh lying on the ground and having their butts within the plot.

G. For each 0.004 ha quadrat

1. Record the number by species of each live standing stem of woody vegetation ≤ 1.3 m in height.

H. For each line transect

1. Record the intercept distance occupied by each of the categories as per the tally sheet.

CUTOVER

BLOCK LAYOUT

A. At least three 1 ha blocks will be established in the area to be harvested.

B. Block, plot, and quadrat layout will be the same as for the Mixedwood Stand.

COLLECTING FIELD DATA

BEFORE HARVESTING

A. Record data as per Mixedwood Stand with the addition of the following:

1. On each 1/25 ha plot (20 m x 20 m) tally all tops with butt diameter > 5 cm by species and butt diameter (1 cm diameter classes). Record all tops which have butts within the plot boundary.

2. For logs and sections of bole > 1 m in length and > 5 cm in diameter at mid-point, record the following:

   - species
   - length to nearest metre (estimate)
   - mid diameter by 2 cm diameter classes.

   Tally all sound pieces which have 50% of their length within the plot.

AFTER HARVESTING

B. For each 0.04 ha plot

1. Tally all standing and downed material as previously. (Trees, logs, and tops > 5 cm in diameter)

C. For each 0.0025 ha plot

1. Tally as previously.

D. For each 0.004 ha quadrat

1. Tally as previously

E. For each line transect

Tally as previously.

ENFOR PROJECT P-191

DISTURBANCE STUDY

BLOCK AND PLOT LAYOUT

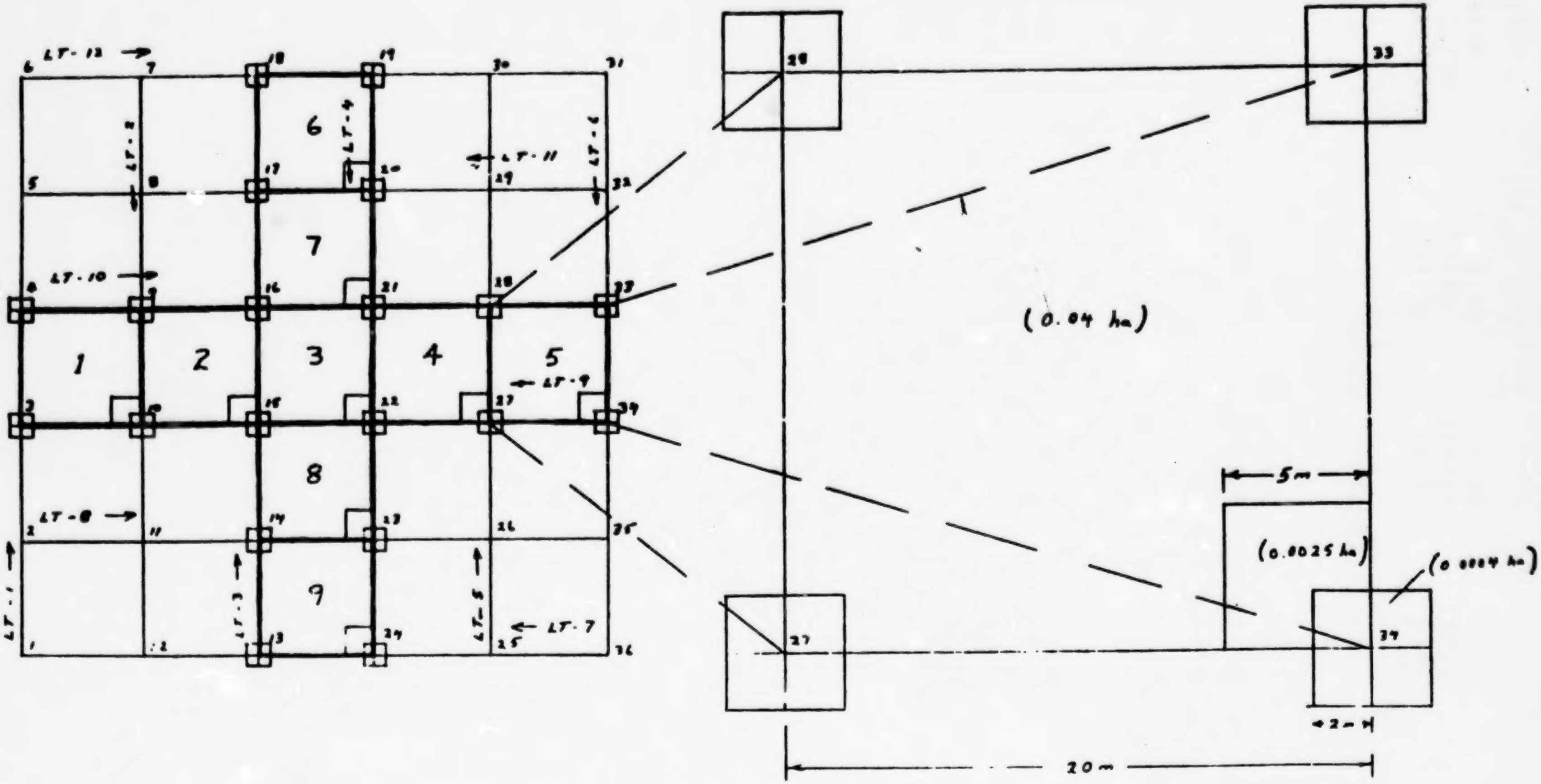
LT-12
LT-2
LT-4
LT-11
LT-6
LT-10
LT-9
LT-8
LT-1
LT-3
LT-5
LT-7
1
2
3
4
5
6
7
8
9
28
33
27
34
(0.04 ha)
5m
(0.0025 ha)
(0.0004 ha)
2m
20m

TABLE 33

APPENDIX 2

BARRELS OIL/TON PAPER

1970 - TO DATE

1970	OIL	ELECTRIC	BARK	TOTAL
BARRELS OIL OR EQUIVALENT	575806	110344	48310	734460
NET SALEABLE PRODUCTION	381404	381404	381404	381404
BARRELS OIL/TON PAPER	1.51	0.29	0.13	1.93
1971				
BARRELS OIL OR EQUIVALENT	436325	119069	30804	586198
NET SALEABLE PRODUCTION	291389	291389	291389	291389
BARRELS OIL/TON PAPER	1.50	0.41	0.10	2.01
1972				
BARRELS OIL OR EQUIVALENT	436002	125712	23382	585096
NET SALEABLE PRODUCTION	268003	268003	268003	268003
BARRELS OIL/TON PAPER	1.63	0.47	0.09	2.18
1973				
BARRELS OIL OR EQUIVALENT	636887	114392	23617	774896
NET SALEABLE PRODUCTION	377786	377786	377786	377786
BARRELS OIL/TON PAPER	1.69	0.30	0.06	2.05
1974				
BARRELS OIL OR EQUIVALENT	595211	55643	37311	688165
NET SALEABLE PRODUCTION	365892	365892	365892	365892
BARRELS OIL/TON PAPER	1.63	0.15	0.10	1.88
1975				
BARRELS OIL OR EQUIVALENT	476182	15750	31492	523424
NET SALEABLE PRODUCTION	246271	246271	246271	246271
BARRELS OIL/TON PAPER	1.93	0.06	0.13	2.12

BARRELS OIL/TON PAPER

1970 - TO DATE

1976	OIL	ELECTRIC	BARK	TOTAL
BARRELS OIL OR EQUIVALENT	533546	25817	36841	596204
NET SALEABLE PRODUCTION	298196	298196	298196	298196
BARRELS OIL/TON PAPER	1.79	0.09	0.12	2.00
1977				
BARRELS OIL OR EQUIVALENT	524825	14046	58215	597086
NET SALEABLE PRODUCTION	367609	367609	367609	367609
BARRELS OIL/TON PAPER	1.43	0.04	0.16	1.63
1978				
BARRELS OIL OR EQUIVALENT	518532	44914	50527	613973
NET SALEABLE PRODUCTION	372587	372587	372587	372587
BARRELS OIL/TON PAPER	1.39	0.12	0.14	1.65
1979				
BARRELS OIL OR EQUIVALENT	521892	6712	64203	592807
NET SALEABLE PRODUCTION	385345	385345	385345	385345
BARRELS OIL/TON PAPER	1.35	– 0.02	0.17	1.54
1980				
BARRELS OIL OR EQUIVALENT	523339	15441	73611	612391
NET SALEABLE PRODUCTION	393866	393866	393866	393866
BARRELS OIL/TON PAPER	1.33	0.04	0.19	1.56
1981				
BARRELS OIL OR EQUIVALENT	515183	17435	89144	621762
NET SALEABLE PRODUCTION	403973	403973	403973	403973
BARRELS OIL/TON PAPER	1.28	0.04	0.22	1.54
1982				
BARRELS OIL OR EQUIVALENT	442570	38209	74735	555514
NET SALEABLE PRODUCTION	320632	320632	320632	320632
BARRELS OIL/TON PAPER	1.38	0.12	0.23	1.73

POOR

QUALITY

ORIGINAL